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THE GENERATION OF POWER.

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No art has developed within the last few years at a more rapid pace than that of the generation of power. This development has been in the line both of an enormous increase in the amount of power produced and in the economy with which it is generated. With this have come developments in the electrical field and so closely are the two related that the unit of measurement of efficiency of our power plants is usually expressed electrically, that is, in the cost required to generate one k. w. of electrical energy per hour, or the amount of fuel, or its equivalent heat value, required to generate a k. w. hour.

The great advance in artificial illumination brought about by the electric light, the establishment and extension of trolley lines for city and interurban service and the distribution of power to both small and large consumers, have heavily taxed the resources of our central power plants, which have been continually increased in capacity to meet the demands. So rapid has been the advance that what was the best practice but a few years ago is in most cases not the best practice of to-day, and it is

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no rare occurrence to see equipments which were up-to-date less than ten years ago replaced by something better. The development of the steam turbine has had much to do with this—a development which has proceeded so rapidly that it must be regarded as one of the marvels of engineering.

Steam is to-day the ruling power. Hand in hand with steam come the gas-engine and hydraulic-power developments. Each has its own particular field and any individual case must be considered by itself before it is possible to say which form of power will be the most economical. Of these three methods of generating power the hydraulic surely has the advantage as far as the conservation of our natural resources is concerned, but history has shown that the development of most water powers is simply a preliminary step to the installation of an auxiliary steam plant to insure continuity of service, and in many cases the power demands become such that the steam plant is eventually the more important of the two. What follows will bear more especially on the production of power by steam.

We often hear the cry that we are a wasteful people and that we should save our coal deposits and make more use of such natural powers as the wind and the waves. These methods of producing power, especially in the case of the wind, have filled particular needs, but as a means of generating the large quantities of power now used for industrial purposes they would be completely inadequate. For example, let us consider the power generated by a single steam turbine of 20,000 k. w. capacity. To produce this power with windmills each having wheels 25 feet in diameter and with a wind velocity of 20 miles per hour we would need over 6000 windmills, and if the mills were placed 50 feet apart they would form a line about 60 miles long.

Again, let us compare the power obtained from the steam turbine with that available from a wave motor. If we should construct a wave motor which would convert half of the total energy contained in the waves into electrical current and which would be operated by a continuous series of waves 200 feet long and 4 feet high, it would have to extend along the coast for a distance of about a mile and a third to give as much power as the single steam turbine. The cumbersomeness and cost of constructing such a wave motor would render it impracticable,

whereas for certain uses where smaller amounts of power are needed a wave motor might be developed to serve the purpose.

Let us consider animal power. A horse develops, say, three-quarters of a steam-engine h. p. under favorable conditions, which means that about 35,000 horses would be required to do the work of the single 20,000 k. w. steam turbine.

The consideration of the subject from a theoretical standpoint is most interesting. The steam-engine is handicapped in its efficiency as compared with the gas-engine by the lower initial temperature of the working fluid in the cylinder, whereas the gas-engine is handicapped as compared with the steam-engine by not being able to make use of a low temperature at the end of the cycle. In a steam-engine a great part of the work is done by the steam at a pressure below the atmosphere, every degree that the condensing water is lowered being available for increasing the work and representing the lower limit of temperature. The steam turbine is especially adaptable for utilizing the low temperature at the end of the cycle. In a gas-engine the lower limit of temperature is that of the hot gases at the end of expansion, a temperature usually higher than the initial temperature of the working fluid in a steam-engine.

The question is often asked why a good arrangement could not be obtained by combining a low-pressure steam turbine and a gas-engine so as to secure the benefits of the high initial temperature in the gas-engine and the low final temperature in the steam-engine. On working out an actual example, however, it will be found that the work of the steam turbine would be comparatively small, amounting to less than 10 per cent. of that of the gas-engine, so that the installation of the steam turbine would not as a rule increase the capacity or efficiency enough to warrant the additional expense and complication of the plant.

Many so-called new cycles for the production of power have been brought out from time to time. In most cases these cycles serve as an illustration of the old adage, that a little knowledge is a dangerous thing. The inventors often work out pages of thermodynamic formulæ to uphold their views. In other cases the problem is dealt with in broad generalities, heat units being handled as if they were packages that could be moved at will from shelf to shelf and so made to pass from one part of the

apparatus to the other without loss, no consideration being given to the amount of surface required to effect the transmission or to the radiation losses. In some cases heat is assumed to be transferred from one part of the cycle to the other, no proof being offered that the interchange will be possible, that is, from a hotter to a colder medium. Still other inventors actually build machines only to find that this is the most expensive way of becoming convinced that they are mistaken. I have had to examine many such schemes and in most cases it could be readily shown that the cycle was at variance with the well-known laws. Cycles that do not conflict with the laws can usually be shown to be impracticable when the sizes of the parts necessary for an actual machine are computed and the radiation losses allowed for. If we could but find a way of disposing of heat at a temperature lower than that of the surrounding objects, we could utilize all of the heat of the ocean or the atmosphere to develop power. Many of the schemes advanced in the so-called new cycles are equivalent to this and the inventors have wasted their energies in striving for the impossible.

Much depends on the load curve of a power plant in obtaining economy. If a continuous uniform load could be carried many of the vexing problems which confront the power plant engineer would be eliminated. It is difficult to carry economically enough reserve capacity to meet the daily peaks in the load. Then again, there are exceptional peaks which occur only at rare intervals, so that a considerable percentage of the available power may be developed only for a few hours every month, or for that matter, for a few hours every year. Modern practice leads more and more to developing higher ratings from boilers during such intervals, and a boiler should be used which, under proper operating conditions, may be driven to a capacity that is limited only by the amount of coal which can be burned in the furnace. Again, it is desirable to use boilers that may be cut into the line quickly either from banked fires or starting from a cold state.

The practice in this respect is exemplified by considering the installations of the Commonwealth Edison Company at Chicago, where the first 5000 k. w. turbines erected in this country were installed. This was in 1903, and eight boilers each having about 5000 square feet of heating surface were supplied for

running a turbine. The maximum rating for these turbines was 7500 k. w. Later on 12,000 k. w. maximum rating turbines were installed, each with eight boilers of the same size as provided for the 5000 k. w. machines. Still later machines of 14,000 k. w. maximum were run with the same size and number of boilers as the original machines of 7500 k. w. maximum.

The steam pressure in power plants of this country is usually about 185 pounds to 200 pounds per square inch and about 150° of superheat is carried. The economy of superheat in this work is well established and represents the best practice.

The steam turbine is becoming more and more the standard for large power-plant work, both on account of its fuel economy and the low cost of attendance. The most economical fuel consumption under operating conditions that has so far been published was obtained in a test with piston engines where a k. w. hour was turned out of the station for each 25,000 B.t.u. contained in the fuel. The station referred to is the Redondo plant of the Pacific Light & Power Company of California, and the results of the test, at which I was fortunate enough to be present, were given by the designer of the plant in a paper published in the *Transactions of the American Society of Mechanical Engineers* for 1908. The fuel was California crude oil. The load curve had two high peaks and the entire plant was shut down during a lay-over period of four and a half hours per day. The 25,000 B.t.u. represent the heat of combustion of the oil used per k. w. hour net electrical output for the entire fifteen-day period during which the test was run. It is a fact worthy of note that this result approaches that to be expected for the plant economy of large gas-engines for the class of service considered where the power is variable and reductions must necessarily be made for all the auxiliaries, etc.

While no results for plant economy as good as the above have been published for steam turbines, it is only fair to say that the figures for steam consumption for turbines show that better than this economy can be obtained under uniform load conditions. When it comes to plant economy so much depends on the load conditions that it is hard to compare one plant directly with another.

We have in this country many large power plants: In New York we have the Edison Waterside Stations and the Interbor-

ough Station; in Boston the Boston Edison Company's Station, and in Chicago the Commonwealth Edison Company's Stations, two of which, built near each other, at Fisk and at Quarry Streets, have an aggregate maximum capacity of over 200,000 k. w. It is noteworthy that the first 5000 k. w. turbines installed in this country, which have already been referred to, were placed in the Fisk Street Station about seven years ago. The rapid development in the art is exemplified by the fact that these turbines are now replaced by others, although at the time they were installed they represented the latest advance in power-plant practice.

The growth in the consumption of power has been so enormous that the question is often asked, Where will it stop? What is a luxury to-day becomes a necessity to-morrow. Where our grandfathers used the tallow dip and oil lamps we must now have a flood of light rivalling that of the sun itself. Our streets are illuminated in a way that our forefathers would have considered impossible and no one would wish to go back to the darkness that would tempt the highwayman and render travel difficult. Ventilating fans are now regarded as a necessity and electrical current is used for a number of household purposes. We could not indeed go back to the old days without giving up many comforts. But where will this great increase in the demands on nature's coal pile land us? This we will have to leave to others to answer. Let us stop for a moment, however, and compare what we are doing with that great silent source of heat and power—sunshine. The sun shining on the world for a single minute imparts as much heat as that contained in all the coal and oil produced in our country in a year, and when we make this comparison we cannot help but appreciate the littleness of our endeavors and have confidence in the great recuperating powers of nature.

After the presentation of the paper, lantern slides were exhibited showing the equipment of several modern power plants and illustrating marine boiler practice. The Fisk and Quarry Street plants of the Commonwealth Edison Company at Chicago were fully illustrated as well as the plant of the Pacific Light & Power Company at Redondo, California.

The type of boiler best suited for power plant work was then discussed by Dr. Jacobus, his remarks on the subject being as follows:

The boiler that is best suited for power plant work, in addition to being

economical, should be capable of being driven with clean feed water to a capacity limited only by the amount of coal that can be burned in the furnace. It should also be of a type that can be gotten under steam and cut into the line quickly, either from banked fires or from a cold state. The thermal storage factor should not be increased by adding to the water capacity to a degree which would sacrifice the ability to get up steam quickly, as under the conditions met in ordinary power plant work an increase in the thermal storage capacity is of less advantage than the ability to get a reserve boiler in on the line in the shortest possible time. The best boilers to use are those that will respond quickly, and by having a number of the boilers in the plant under steam and others in reserve the steam pressure may be maintained practically constant. To make thermal storage a material factor the steam pressure must fall, say, 25 pounds or so, and after the pressure falls the thermal storage will act against the recovery of the pressure, hence during the period of recovery the rate of combustion of the fuel and the heat imparted to the boilers must be greater than with the boilers having a less thermal capacity.

The great problem in power plant engineering is to economically carry enough reserve capacity to meet the daily peaks of the load. Then again there are exceptional peaks which only occur at rare intervals, so that a considerable percentage of the available power may be developed only for a few hours every month, or for that matter, for a few hours every year. For this class of work the Babcock & Wilcox boiler has proved to be pre-eminently successful, so much so that it has been one of the important factors in power plant development. It is good modern practice to drive these boilers daily at double the nominal rating during peak load periods. This does not mean that the boiler is driven to an overload in the sense that it is under a strained condition of running, as the rating of 10 sq. ft. per boiler horsepower is simply an arbitrary one. The speaker believed that eventually boilers would be operated harder than this during peak load periods, and that additional plant economy would be secured thereby.

In marine boiler practice Babcock & Wilcox boilers have been driven to give an evaporation about four times as much as that based on the nominal rating of 10 sq. ft. per boiler horsepower, hence there is a considerable margin for increasing the rate at which boilers can be driven in power plant work. The economy at this high rate of driving does not fall off as much as one might expect, as most careful tests show that the efficiency of a Babcock & Wilcox marine boiler for such an overload is over 60 per cent. In power plant practice it would pay to run the boilers at a high rating during peak load periods even though the efficiency should fall lower than this, because a great saving is effected in cutting down the fuel required to keep banked fires in the boilers held in reserve and to bring up cold boilers to be run during the peak load intervals. With chain grate stokers, such as were described in connection with the Fisk and the Quarry Street Plants, the best efficiency is reached at slightly over rating and remains constant to nearly double rating. The reason for this is that as the rate of combustion of the coal becomes greater the furnace efficiency increases to a sufficient extent to offset the loss of heat absorptive efficiency of the boiler. It is therefore apparent that under these conditions the best commercial economy is obtained

by following the practice described and operating the boilers at double the nominal rating.

Some questions were asked by a member in regard to tube failures in Babcock & Wilcox boilers. He said he had been informed that after the marine boilers were run in a trial for maximum speed the lower tubes were sprung and distorted and that the circulation was defective under certain conditions, so much so as to cause accidents through tube failures. He further said that in his opinion a greater amount of boiler heating surface than the present practice calls for should be provided for power plant work, rather than a smaller amount.

In replying Dr. Jacobus said that one of the requirements for boilers for the U. S. Navy, where many of the marine boilers are installed, is that the boilers shall show no distress after being forced during a trial of maximum speed and subjected to an endurance run, and that as the acceptance of the boilers depended on conforming with this requirement it would be evident to anyone that there were no grounds for the statement which had been made. Furthermore, he said that he could certify to the fact from personal observation that the tubes were straight after such endurance runs. When it came to circulation he could further say that he had made tests which indicated that there was a large margin of safety in this respect. He had made tests on a boiler where the tubes were 20 ft. long instead of 18 ft., as adopted in power plant practice. In these tests the lowermost tubes were heated their full length by hand firing bituminous coal on a grate which extended under the entire boiler and the boiler was run for weeks at over two-and-a-half times the ordinary rating, with no distress to the tubes. He further said that in these tests the steam pressure on the boiler had been varied by special means so that it was made to fall suddenly and was afterwards made to recover in as short a time as possible, thus indicating that any variation in the flow of the steam from the boiler would not cause trouble. In some of the tests the boiler was driven to over three times its rating. Ordinarily less than one-half the length of the lowermost tubes are subjected to the full heat, hence, as the tubes in the experimental boiler were 20 ft. long instead of 18 ft., it would follow that the heat imparted to the lowermost tubes was two or three times that which ordinarily exists during peak load periods in power plant work, showing that there is a large margin of safety. He further said that the tubes remained in good shape under severe service conditions at the Fisk and Quarry Street Stations, where the boilers are run continually when in service at almost double their rated power, one boiler after another being cut in to carry the load. At the time he was at Quarry Street two insurance inspectors had gone over all of the boilers and had ordered out only one tube, and even this single tube was not in a very bad shape. In reply to the statement that more surface should be provided per horsepower than that ordinarily adopted in power plant work, Dr. Jacobus reiterated that, in his opinion, for this class of service where there are peak load periods the amount of heating surface per kilowatt output will be decreased instead of increased as the art advances.

With perfectly clean water there is little danger of tube difficulties, whereas if the least trace of oil finds its way into a boiler it may cause

trouble, especially if salt, due to leakage at the condenser or from some other source, is present at the same time. A loose scale may also cause trouble. The action of such foreign substances inside the tubes is to cause blisters, which ordinarily will bulge out and possibly open slightly. If it so happens that there is a flaw in the tube at the point where the blister is formed, the tube may open up, and if the opening is large enough an accident may result if anyone is caught in a confined space and cannot get away from the boiler. A boiler under steam is a magazine of energy and just as long as boilers are used there may be accidents. Disastrous explosions, however, such as we often hear of in connection with shell boilers, are impossible with Babcock & Wilcox boilers, and the Company takes particular pride in the fact that the Babcock & Wilcox boiler is universally conceded to be the highest type of the "so-called" safety boiler.

A number of other questions were asked and were replied to as follows:

Engineers differ as to the best size of boiler for power plant work; personally, he believed in units of about 500 or 600 h.p., as with larger units, say, of 1000 h.p., cutting out a boiler for cleaning or repairs would diminish the capacity to a greater extent proportionally than by cutting out one of the smaller units.

The superheat cannot become excessive so as to give a temperature in the neighborhood of 1000° F. with a Babcock & Wilcox superheater placed within the boiler setting, as one of the audience had heard that it might. Actual measurements show that the superheat is comparatively uniform instead of varying through any wide ranges of the sort. The only time that there could be an excessive superheat would be when the power is suddenly thrown off the boilers when the latter are working at their maximum load, which might occur if there is a short circuit in the electrical apparatus. In this case it might seem that with only a very small amount of steam flowing through the superheaters, or possibly with no steam at all, and the fires burning up to the maximum, the superheaters would be greatly overheated. Such is not the case, however, as each superheater is fitted with a safety-valve which blows at a few pounds less than the main safety-valves of the boiler, and in such an emergency the steam will circulate through the superheaters and in this way eliminate any excessive superheat.

Measurements of superheat taken on a single boiler may vary to a considerable extent on account of irregularity in the operating conditions; for example, should the water tender allow the water to get low in a boiler and then feed the boiler up quickly with cold water, the steam generated by the boiler during the feeding-up period would be considerably less than normal. During this time less steam would be flowing through the superheater in proportion to the heat outside of it than under normal operating conditions and the superheat would increase. Variations in the furnace conditions also cause the superheat to vary. Where the steam from a number of boilers is mingled before passing it to a steam-engine or turbine the irregularities are averaged and the superheat will be comparatively uniform.

In regard to loss of economy due to excess air: it is a fact that much could be gained in many plants by reducing the amount of such excess. It should be remembered, however, that in making analyses of flue gases the

carbon monoxide should be determined accurately as well as the carbon dioxide. In many cases a small amount of carbon monoxide may escape notice in the analysis, whereas it may have a considerable effect in reducing the economy. In analyzing for carbon monoxide two absorption pipettes should be used, the second pipette being employed to remove any of the gas not absorbed by the first. The solution should be fresh and active. In obtaining the highest efficiency it is often more difficult to eliminate the carbon monoxide than to obtain a high carbon dioxide reading.

The class of attendance in boiler room work was next discussed. The managers of power plants are now appreciating the fact that it pays to obtain the services of high-class men in the boiler room, and a much better class of boiler room engineers are employed than formerly. More can be lost or gained in the boiler room than in any other part of a power plant, and it is false economy to employ other than a capable engineer, as such a man can save his company many times the cost of his services.

The advisability of casing-in power plant boilers with a metal covering to eliminate leaks through the setting was also discussed. This method of eliminating leakage is growing in favor, the advantage gained over a leaky setting justifying the additional cost.

The question was asked how much scale should be allowed to accumulate in a boiler before cleaning. The reply to this was that a feed water which would form any material amount of scale should be given a preliminary treatment that would prevent any scale forming in the boiler. It is dangerous to attempt to loosen the scale in a boiler operating under working conditions, as a piece of loose scale or a little pile of the loose scale may prevent the water from acting on the inner surfaces of the tubes and a blister may result. When using a water which forms scale very slowly it would not seem advisable to run with much over a $\frac{1}{32}$ in. scale in the tubes; in any event, the scale should not be permitted to accumulate to such an extent that it cannot be readily removed by a turbine cleaner. In case a boiler has been allowed to accumulate a hard scale it is often well to soften the scale before attempting to get it out with the cleaner, but in softening the scale the boiler should be cut off the line and run with a slow fire, any steam generated being allowed to escape through the safety valves.

Aeroplane Construction. W. H. MILLER. (*Amer. Mach.*, xxxiii, 29.)—A most interesting and instructive article that will repay careful perusal. It might be summarized thus: The framework is made of many different materials; while bamboo is light and strong, its natural joints interfere too much with construction, so light bicycle steel, hickory, and ash are substituted. Many constructors consider wood preferable to steel for parts under compression as less liable to buckle. Steel wire, tautened by turnbuckles, or U bolts, is used for tension members. Rubberized linen is used for wing surfaces. Wings are sometimes made to fold. The location and control of the stability planes varies, in the endeavor to use as few levers as possible.

RECENT ADVANCES IN THE CONSTRUCTION OF FIRE- AND BURGLAR-PROOF SAFES.

(*Read at Stated Meeting of the Institute, held Wednesday, October 19, 1910.*)

BY

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[In this article is presented an interesting account of the progress made in lock-making and safe-building during the past century.]

In order to place before you the recent advances in the construction of fire- and burglar-proof safes, it is necessary to cover a brief history of the industry from its actual beginning in the early part of the Nineteenth Century down to the present time.

Practically speaking, the more recent advances have had to do principally with refinements in mechanical processes, the development of factory organization and the perfection of elements of design that were conceived long before the means were at hand for their proper realization.

The development of any industry is in a large measure dependent upon the activity in other related industries, and the progress in the one must mean a general forward movement on the part of all.

The development of the art of building safes for the protection of valuables is interwoven so closely with that of the art of lock building that the two subjects necessarily must be treated together.

It is a fact that is apparent to anyone who gives consideration to the subject, that a safe, however secure from the stand-point of construction, would be useless without an opening giving free access to its interior, and that opening guarded by a lock at least as secure in point of design and construction as the safe itself.

The conclusion must be drawn from this that safe building, in point of relative security, could only keep pace with the development and with the design and construction of locks. The history, therefore, of the development of the safe building art is in reality, first, the history of the development of locks.

Locks, as we know them to-day, and as they have been known ever since they were first used, consist primarily of a bolt and a key for operating the bolt, and some means interposed between the key and the bolt to render the operation of the bolt either more or less difficult or impossible without the use of the proper key.

The means employed for housing the working mechanism of the lock, and for applying it to the protected structure, are of little importance in this consideration. All of the different locks possess these features. They may be divided into several general classes.

First, not only in point of simplicity, but naturally also in point of historical origin, is the latch lock, in which there is a bolt pivoted on a fixed point and raised by some sort of a key.

Locks were later rendered more secure by the introduction of the warded type in which the introduction of the key into the hole provided for it was rendered more or less difficult by means of interposed wards, making it, to a degree at least, impossible to introduce the wrong key.

The warded type of lock was succeeded by the present day lever tumbler type, in which tumblers are interposed between the key and the bolt, making it necessary for the key to lift the different tumblers before the bolt can be withdrawn. This type of lock is considered secure in proportion to the number of tumblers used and the means provided for varying the relative amount of lift.

The bolt of this type of lock has fitted to it a member that passes into slots in the lever tumblers in the operation of its withdrawal, and the province of the key is to line up these slots in the lever tumblers so that they register with the fixed member on the bolt.

A later development of the tumbler type of lock is that known as the cylinder pin-tumbler lock. In this type of lock the obstruction consists of divided pins preventing the turning of the plug until these pins have been raised to a point where the division line between the different sets of pins coincides with the outer surface of the plug, and the inner surface of the cylinder, in which it rotates. When these points have been so lined up by the introduction of the proper key the cylinder may be rotated and the bolt withdrawn.

The inconvenience resulting from the use of the ordinary type of key lock, by reason of the fact that keys could be wrongfully

duplicated, or they might in various ways come into the possession of persons not entitled to them, gave the necessary impetus to inventive genius, and the modern dial or combination lock was the result.

Coincident with the development of the dial lock is that of the changeable type of key lock, in which the arrangement of the tumblers or obstacles may be almost indefinitely varied. It practically, after being set up to a new key, becomes an entirely new lock and cannot be operated by any other key than that to which it is set up.

The development of the changeable-key type of lock is of great importance for the reason that a limited amount of security is frequently needed of a kind that cannot be afforded by the ordinary type of lock. This security is frequently furnished by combination or dial locks that are much more expensive.

The changeable key locks, until recently, have been of a design and construction that were very apt to get out of order and cause considerable inconvenience to the user.

Many efforts have been made to produce a simple lock of the changeable-key type, all of them depending upon the introduction of a double tumbler between the key and the bolt. The changeable-key lock that is being manufactured by the Herring-Hall-Marvin Safe Co. is the only one in which the obstacle that is interposed consists of a single member. The tumbler of this lock departs from the lever tumbler type previously employed in that it has no fixed pivot but can be properly called a balanced tumbler.

Its greatest merit is its simplicity and its substantial construction. In all other types of changeable-key locks the means provided for changing the combination are delicate, and in the ordinary operation of the lock the wear on these delicate parts is constant. In this lock the means provided for changing the combination are not in the least delicate, and the ordinary operation of the lock in opening and closing after it has been set up to a key causes absolutely no wear on the combination part of the tumbler, making the lock just as substantial, and as little liable to get out of order as the simple lever tumbler type of lock.

It is generally conceded by those who are interested in the manufacture and sale of locks that the changeable-key type of lock has been greatly limited in its use heretofore by reason of its delicacy, and its propensity for getting out of order.

As an evidence of the simplicity of the Herring-Hall-Marvin Safe Co. lock, it is necessary only to call attention to the fact that in this lock, which admits of over 59,000 different changes, there are but 14 parts, while in the highest type of changeable-key lock previously invented, which afforded but about 8000 changes, there were over 40 parts.

Its application, while not exactly universal, is broad enough to enable it almost entirely to supplant the other types of key locks.

In the case of apartment houses, where tenants are constantly changing, the ordinary type of lock affords absolutely no security, for the reason that keys may be duplicated. With the changeable-key type of lock it requires but an instant of time to set up the lock to a new key and thereby render all previous keys inoperative.

The combination lock, as it is known to-day to distinguish it from the key lock, became a necessity when it had been demonstrated that practically all key locks could be picked. This fact was developed in the historic lock controversy of 1851, in England, when Mr. Hobbs succeeded in picking all of the best makes of locks.

A few years later, to be exact in 1856, Mr. Linus Yale, Jr., succeeded in picking several of the Hobbs locks. It then became generally conceded that no difference what the obstacles were that were interposed between the key and the bolt so long as an opening was left for the insertion of the key, this same opening provided means for the insertion of picks to raise the tumblers. Mr. Yale then turned his attention to the designing of a lock that could be operated in some manner other than by the insertion of a key, and the early type of combination lock was the result.

The combination lock, being in such general use to-day, needs no lengthy description. It consists of the tumblers, the bolt, a lever member interposed between the tumblers and the bolt, and a spindle or arbor, having on its inner end a driving tumbler and on its outer end a dial. The lever member is usually characterized as a fence, and is, from the stand-point of security, a very important part of the combination lock.

The first locks were fitted with a gravity fence, and it was later found that the disc tumblers could be rotated so as to bring their notches in line with the fence even when the combination

was unknown. The fence rested upon the periphery of the discs and could with patience and a delicate sense of touch, be felt into the notches one at a time until all of the discs were lined up, when the bolt could be retracted by simply turning the dial. This defect was a serious one. It was finally overcome by Mr. Emory Stockwell of the Yale Bank Lock Department, by the invention, in 1884, of the balanced fence. This fence was so supported that it brought no weight to bear upon the periphery of the tumblers. It was fitted with a friction bearing and could be moved out of its neutral balanced position only when the tumblers or discs had all been lined up in registry with it.

This improvement rendered the combination lock absolutely unpickable. It, however, remained for the ingenuity of the burglar to devise ways and means for defeating even this supposedly perfect lock. It was evolved out of the fertile brain of some enemy to organized society, that a mental key always existed and could be secured by torture—the combination numbers were always known by some one. There began, in the year 1874, a series of bank robberies all over the United States, the most important of which were carried to a successful termination by reason of this one weakness of the combination lock.

It immediately became evident that a lock with absolutely no communication with the outside of the protected structure was necessary and essential to security, and the invention of the time lock followed. This was and still is, to a large extent, used in connection with the combination lock. Its use prevents the operation of the combination lock until such time as the time lock has run down and, by so doing, withdrawn its obstruction to the operation of the combination locks themselves, or the means provided for opening.

Meanwhile, in an entirely different field, inventive genius had been equally active by the invention of liquid high explosives, the fluidity of which could be increased by the addition of liquefied ether, so that it could be made to flow into the space surrounding the lock spindles or into the joint between the door and the frame. The burglar, without first securing any proprietary rights in the invention, adopted this method and the battle of wits began over again, with the result that the lock makers finally evolved a motor device working in conjunction with a time lock, which made it unnecessary to connect the outside of the door with the

inside by means of spindles. The motor after being set would throw the bolts, when the door was seated into the jambs, and would instantly retract them when tripped by the running down of the time lock.

The motor device has not been universally adopted for several reasons, mainly because spindles can be, and are, made so that they cannot be driven in or pulled out, and they can be, and are, made drill-proof. They are ground into the doors so closely that no liquid can be forced around them.

In concluding that part of this paper which relates to locks, I desire to call attention to the fact that while practically all types of key locks can be picked, it does not follow that the key lock should be discarded, for the reason that the measure of security afforded by the lock need not be greater than that afforded by the protected structure itself. Manifestly a light wooden door affords very little security, yet millions of them are fitted with locks. Some with the common warded type, others with the lever and pin-tumbler types—all at least affording a measure of security equal to that of the protected structure itself.

That these locks can be picked is no argument against their use because entrance could be had in nearly all cases in an easier way. The inherent defect in all key locks, other than the changeable key type, lies in the facility with which keys may be wrongfully duplicated and used, rendering such locks of no security whatever.

The fire-proof safe which will protect its contents from destruction and bring them safely through such fires as that following the San Francisco earthquake, the Baltimore fire and the Parker Building fire, is of very modern origin.

No historical evidence exists of the use of safes for protection against fire earlier than about the year 1820, at which time a portable fire-proof safe was constructed in France. This safe consisted of an outer and an inner metal box with a space between filled with some form of non-conductor. No information is obtainable regarding the details of construction or the materials used. Previous to this the only form of fire protection afforded consisted in vaults built of masonry, which, owing to their cost, were limited in use.

In the year 1826 a fire-proof safe was invented by J. Delano. This safe was made of oaken planks three or four inches in thick-

ness, which were saturated with salt brine to render them to some degree fire-proof, and were covered on the outside with bands of iron held in place by wrought iron nails. This safe afforded only a moderate amount of fire protection. Many of them were destroyed in the great fire in New York in 1845. A safe of this type is now in the possession of the Herring-Hall-Marvin Safe Co. at its Hamilton factory.

Some time between the years 1829 and 1832 Jas. Connor, of New York City, constructed an iron box with a filling between the walls composed of plaster of Paris. He used this safe in his own office but made no attempt to patent or manufacture it. In 1834 William Marr, of England, patented a safe, the peculiar feature of which consisted of sheets of mica pasted on paper, the space between the mica sheets being filled with burnt clay and powdered charcoal mixed.

In 1838, Chubb, of London, produced a safe in which a series of iron plates were used with intermediate spaces packed with wood ashes.

Coincident with these, various other freak safes were patented and placed upon the market, but none of them seem to have left any impress of their individuality on the development of the safe industry.

The first real safe patented, manufactured and put upon the market as a commodity, was introduced by Daniel Fitzgerald, of New York City, in 1834. In this safe the fire-proof composition consisted of plaster of Paris, which was first baked and then reduced to a powder, after which it was mixed with water and mica to the consistency of paste and was poured between the outer and inner walls. This filling was a good fire resistant but its chemical action upon the iron plates composing the walls of the safe was such that it weakened the construction and rendered the safe entirely worthless in a short space of time.

Mr. Fitzgerald early associated himself with Azor Marvin, who founded the Marvin Safe Co. and was long considered one of the heads of the safe industry. This Fitzgerald safe was known as the "Salamander" safe, to distinguish it from the wood-lined chest built by Delano.

In 1843 Tann Bros. invented and patented a safe which depended for its fire-proofness upon a filling consisting of ground alum mixed with powdered gypsum. These elements were thor-

oughly mixed and melted together after which the mixture was pulverized and converted into a coarse powder and used in this form for the filling of the safe. The mixture when subjected to extreme heat would give off water. This safe was known as the Marvin Alum and Plaster Patent, and was exploited for many years.

During this time numerous other dry filled safes were invented and placed upon the market. Various kinds of heat-resisting elements were used in the filler, but the safes were not a success on account of the fact that in some instances the steel walls of the safe were corroded by the filler, and in other instances the heat-resisting qualities of the material used was low and many of these safes,—in fact the majority of them,—failed to preserve their contents when subjected to the test of great fires.

The industry was not placed upon a solid and substantial basis until after the modern concrete filling came into use. In 1865, when Jos. L. Hall, of Cincinnati, Ohio, the then President of the Hall's Safe & Lock Co., patented what was known as Hall's Matchless Concrete Filler, a safe was made that would withstand severe fire tests and would actually improve with age. This filler was composed of cements mixed with certain liquids and contained a large proportion of steam-producing elements in solid form. In addition to its non-combustible and non-conductive qualities, it has the other important advantage of materially strengthening the entire structure. It also improves with age instead of disintegrating in the manner of all other fillers that had previously been used.

The claim is made that when heat is applied to a mixture such as this, the liquid element that is contained within it, not in a liquid form, however, but in what has been characterized as water of crystallization, is upon the application of this heat converted into steam, thereby changing the heat into work and rendering it latent.

The most successful dry fillings previously used depended for their heat-resisting qualities upon this same principle, but were a failure on account of their destructive action on the steel walls of the safes, and for the further reason that they did not add any strength to the structure.

In the event of a fire a safe is apt to be subjected to a fall, sometimes from the upper floor of a building to the basement.

Its construction must be such that it will withstand this fall without exposing its interior to the destructive action of the flames. In the case of a dry-filled safe the exterior shell of metal is apt to be punctured and the dry filling sifted out, leaving some part of the safe entirely unprotected.

The concrete filling above mentioned strengthens the entire structure and by the test of great fires has proven that this added strength is one of the greatest points in its favor. The concrete filling invented by Jos. L. Hall has been improved upon and is now used exclusively by the Herring-Hall-Marvin Safe Co. in the filling of its entire line of fire-proof safes.

During the development of the industry much thought was expended upon the construction of the framework and jambs of the safe itself. A good grade of cast-iron is used in the jambs of the door and the body of the safe. This is used for the reason that cast-iron will withstand greater heat without warping than bars or plates of steel or iron. The framework of the outer box is made of angles securely welded at the corners. These angles add strength to the jamb casting and prevent its breakage in case of a fall. The outer door-plate performs the same function for the casting which serves as the jambs of the door. Particular attention is directed to this combination of metals.

The cast-iron, which will not warp under great heat, but which is apt to break as the result of a fall.

The steel angle-frames and the door-plate which add the necessary strength to the castings so that they will be able to withstand the shock of a fall.

The fire-proof safe made fifty years ago, and filled with the concrete filling, was a creditable article considering the advances made in related industries. It was not fitted, however, with an angle-hoop and the outer body of the safe was necessarily much weaker than in the safes made to-day. The fit of the doors was less accurate, and the workmanship in general, as might be expected, not approaching to any degree that of to-day.

The safe had many defects. The castings mentioned above were cut away on the hinge side of the door for the lodgment of the hinges. The hinges were made with an interlocking lug or boss that closed in back of the frame. The construction was bad on account of the added metal which tended to conduct heat into the interior of the safe, and the weakening effect which it had

on the frame on account of the metal that had to be cut out in order to provide space for the hinge.

The recent advances in the construction of fire-proof safes consist:

First, in the Matter of Patterns for Door and Frame Castings.—These patterns have been revised and reconstructed at large expense with a view to securing a better fit between the door and its frame. Foundry practice has improved to such an extent that castings can now be secured with much less variation in size than formerly. To keep pace with, and to take advantage of, this advance in the art of making castings, it was necessary to reconstruct the patterns. When this was done seven years ago, the tenon and groove and the interlocking-jamb features were incorporated in all of them that had not previously been so constructed. We are now using moulding machines in the making of many of our door and frame castings, which has enabled us to further reduce the limit of variation in the size of the castings themselves and to fit together a door and frame with the smallest possible allowance for variation in size of castings.

Gray iron castings can now be made that will withstand a high degree of heat without warping. In the production of our castings we use those materials which have been determined by experiment to be the best adapted to the production of a casting of uniform size, strength and rigidity.

The effect of the close-fitting door, together with the features of the tenon and groove and interlocking flange, upon the relative fire-proofness of the safe is great. A closely fitted door braces and reinforces the strength of the frame, while a loose-fitting door adds the weight of its overhang to the frame and weakens it in direct proportion to the looseness of the fit.

Second, the Framework.—The old style band hoop or frame has been superseded by the solid welded angle-frame. The front frame supports the jamb casting and provides a fastening for the hinges. This angle is a vast improvement over the old style band or bar frame.

The manner of welding the corners is of the greatest importance. We have found by experiment that the best and strongest results can be obtained only by the hand method of welding. After the angles have been mitred at the corners the edges to be joined are hammered out hot by hand, so that they

will overlap each other when bent. The actual welding operation is then performed by hand and the strength of a corner so produced has been found by test to equal in nearly all cases the strength of a solid section of the angle itself—a result which we have found impossible to arrive at by any other method.

The outer section of the safe has been strengthened by reinforcing wherever experience has shown such reinforcement to be necessary. At the same time no unnecessary weight has been added. In fact, any weight that does not add proportionately to the strength of the whole structure is a serious detriment in case of a fall. In the modern safe we provide angles and bars between the front and rear frames. The angles are placed at the corners and the bars midway between. These are securely tied to the frames of the safe and provide additional means for fastening and supporting the outer steel wall. This outer steel wall, as well as the inner steel wall, is made heavy enough to properly support and retain the fire-proof composition, and light enough so as not to add any superfluous weight to the safe.

The proper proportioning of the parts relative to each other, and to their various functions, is a matter that has been given the most careful consideration in the development of the modern fire-proof safe.

The doors are hung on malleable iron ball-bearing hinges. These hinges are fastened on the outside. The introduction of the interlocking flange in the rear of the door has made it no longer necessary to mortise them into the door and jambs. The burglar would gain nothing by knocking them off. The ball bearings by their resistance to wear maintain the door in its proper relation to the frame, and provide the additional feature of ease of operation. The outside hinge as now used makes it unnecessary to cut away part of the strength of the frame as was formerly done while the inside hinge was used.

The operation of the bolting mechanism has been simplified by being made more direct. The locks now used on the outer doors are of the combination type. They are protected by steel plates to prevent drilling and the arbors or spindles are shouldered to prevent driving in or pulling out.

An additional device is also provided that will automatically hold the bolts in the locked position in case the lock is in any manner rendered inoperative.

Those features in their best form are all of comparatively recent origin, and have added much to the value of the protection afforded by the modern safe.

The inner steel doors of fire-proof safes have heretofore been guarded by ordinary key locks. The same is true of the small cash boxes usually found as a part of the cabinet equipment. In the very near future the Herring-Hall-Marvin Safe Co. will equip all of its inner doors and cash boxes with changeable key locks, thereby adding greatly to their security by the facility with which keys may be changed by the user.

A complete line of steel interiors fitted with the most improved modern filing devices will shortly be completed and placed upon the market by this same company. This will be a great advance over the type of interiors now in general use.

To the above-mentioned improvements have been added numerous other minor refinements that result from better mechanical methods, modern factory organization, and thorough inspection.

There has lately been placed upon the market by the Herring-Hall-Marvin Safe Co. a modern safe fitted with a built-in system of electrical protection. This safe may be connected to a central station system or may be fitted with a local alarm. In appearance it resembles closely the ordinary fire-proof safe and is a marked improvement over the types of electrically protected safes now in use, which depend for their security upon a separate electrical cabinet encasing the safe.

In this new safe the electrical circuits are built into the safe itself. The circuits are so arranged that any attempt to wrongfully gain entrance to the safe by the manipulation of the locks, by drilling, or by any other method, will cause an alarm to ring.

The circuit connecting the safe with the alarm is a closed one and is so arranged that it cannot be tampered with without causing the alarm to ring. The Herring-Hall-Marvin Safe Co. owns and controls the patents covering this type of construction.

The so-called burglar-proof safe or vault has been improved and perfected in many ways in the last ten years.

The development of the burglar-proof safe depended in a large measure upon the development of the steel industry, and to a great extent also upon the development of locks. Until such time as really burglar-proof locks had been perfected no great

advance could be made in the development of the burglar-proof safe or vault.

The burglar-proof safe of to-day must be drill-proof, it must be fitted with a door that seats so closely into the opening provided for it that no liquid explosives of any kind can be forced between the door and the jamb.

Its bolting mechanism must be of sufficient strength to retain the door in its seat and it must be controlled by locks, the operation of which will leave no opening through the door for the introduction of explosives.

The modern method of arriving at these conditions differs greatly from the attempts that were made years ago. Drill-proof steel, as formerly used, consisted either of Franklinite, which was cast or poured between two solid metal walls and allowed to harden in place, or strips of so-called spring steel laid between two retaining plates of soft steel.

The drill-proof steel used in the construction of the modern burglar-proof safe or vault is what is known as five-ply steel. It consists of alternate layers of hard and soft steel rolled and welded together, the result being a plate that will, when tempered, successfully withstand the hardest drill and will yet retain enough tensile strength to resist the crushing and rending effect of modern explosives. This steel was not available in the older types of construction. It is now in general use.

The most recent improvement in burglar-proof construction is the round-door safe, and the round-door bank vault. The increased closeness of fit that can be made in a round door between the door and jamb, and the possibility of actually grinding the door to its seat, makes this type of construction the highest in existence to-day.

The amount of protection afforded by the lighter forms of construction that were in use fifteen or twenty years ago, is in the light of present-day developments very inadequate. It is only in recent years that the jambs, or the union between the door and the frame have been polished. Earlier than this the machining was roughly done, and if too much opening was left a free use of putty and paint at least made an appearance of a fit.

All this has been changed, and for the past eight or ten years no burglar-proof door has been made by a reputable builder that

does not show the polished metal on the edge of the door and jambs.

There are two general types of construction in use to-day, one being characterized as laminated construction, consisting usually of alternate layers of open-hearth steel and five-ply steel, and the other being what is known as insulated constructions. This latter contains an outer section of cast steel containing in its construction insulating materials in which are embedded drill-proof rods or bars, and an inner section of laminated construction.

The intention in this latter construction is to eliminate the danger of burning by the electric arc, by Thermite, or the oxy-acetylene flame.

There has been much discussion as to the possible use of these agents by the burglar. It is a fact, however, that long before they were considered in this connection the modern builder of bank vaults had made many experiments and had devised ways and means of overcoming practically all the danger from these sources. Many of the older types of bank vaults, however, are not as well protected in this way as are the recent ones.

The general tendency was up until recent years, to build vaults very light in construction. An eight-inch door was considered a very heavy one. Now doors are built as thick as twenty-eight inches, and one is now in course of construction in the factory of the Herring-Hall-Marvin Safe Co. that will be, when completed, thirty-eight inches thick from the outer face of the door to the inner face of the bolt frame plate. The total thickness over all from the surface of the operating mechanism of the door to the extreme inner surface of the glass door covering the bolt work will be sixty-one inches.

The greatest advances, however, in recent years in burglar-proof construction have been the result of the application of up-to-date mechanical methods in their production.

Modern drill-proof steel gives absolutely adequate protection against the use of the drill. Steels formerly used and incorporated in the construction of bank vaults were not, however, drill-proof to the extent that this quality exists in the present-day steels. These older types of vaults therefore are not as thoroughly burglar-proof in this sense as are the more modern ones.

When the vault manufacturer succeeded in producing a bank vault that would successfully withstand the use of a drill, he

found that his vaults were subjected to attack by the use of the wedge in the crack of the door itself. The closeness of the fit of the door did not in any way interfere with the successful use of the wedge.

A system of interlocking jambs was devised which in a measure would prevent the springing of the frame away from the door, and this reinforced by the more recent overlapping flange, which makes it impossible for the burglar to use a wedge on one of these modern doors, has eliminated entirely this source of danger. No owner of a modern bank vault need fear either the drill or the wedge.

The same security exists in reference to lock spindles that are used at the present time. Formerly these were carelessly fitted and openings could be found around them for the introduction of liquid explosives. Now they are so carefully ground into the doors that it is impossible even with pressure to force around them any known liquid explosive.

The same close fit is now also made of the door in its seat. Every modern bank vault entrance is subjected to what is known as the water test, and the door must fit so closely into the jambs that it will resist the passage of water between the door and frame.

The operating mechanism of the bolt work has been greatly improved. Formerly the bolts were operated through a system of levers and bell cranks that were indirect in their action, and were frequently the source of great inconvenience to the user. The modern boltwork is operated through gears and racks, and is so balanced in its action that very little effort is required in locking and unlocking.

The hinges are better adapted to the service expected of them. In all modern vaults the doors swing on hinges fitted with ball and roller bearings of the very best design, workmanship and materials, making a door of many tons weight so easy to operate that a child can swing it in and out, yet so perfectly balanced that it will stand at any point. These bearings are fitted with means of adjustment to compensate for wear.

The pressure mechanism for seating the door into the jambs has been improved in design and construction.

The inner surfaces of the front jambs on all of the best examples of the modern doors are brought to a uniform plane to

provide a perfect seat for the locking bolt wedges. These wedges have an inclined inner face parallel to the bevelled bearing face of the bolts themselves. These bearing faces are made as broad and large as possible, and the wedges are separately adjusted and fitted under the bolts so that when the door is seated and the locking bolts thrown the holding and retaining power is uniformly distributed throughout the entire system.

The modern means employed for binding the locking bolt mechanism to the body of the door consists in tapering or conical bolts running well into the body of the door, each bolt separately fit to its seat, and all binding the bars through which the locking bolts operate firmly and securely to the door This method of fastening and fitting makes the door with its bolting mechanism an indivisable unit; the holding and retaining power equalling the great strength of the solid section of the door itself.

In the older types of construction revolving bolts were used. The fit of the doors was so imperfect that it was feared that the burglar might pass a saw through the crack of the door and saw off the locking bolts.

The structure guarded by the door, or entrance, which in common practice is called the lining, has been strengthened and improved upon in many ways. The modern lining is built up of alternate layers of steel plates. A combination is made of plates of unusual toughness and high tensile strength, with drill-proof plates of five-ply welded iron and steel, all bound together and protected at the outer and inner corners by massive steel angles. The plates of adjoining layers are laid at right angles to each other and the size of the various plates are calculated so as to break joints. The surfaces of all plates are rolled to perfect planes and the edges of plates and angles are ground to a liquid proof fit. The angles at the corners are welded into three-way members that effectually bind the vertical and the top and bottom faces of the lining together.

The steel plates used in the construction of the modern vault will resist the penetration of the best drills. The high tensile plates will successfully resist all explosives, and the ground joints prevent the introduction of liquids.

Steels of the quality in use to-day were not obtainable in the earlier years of the industry. Machinery and machining methods were crude, and factory organization as it exists to-day with its

team work and all of its multudinous aids to rapid and perfect production was undreamed of.

All the foregoing that relates to improvements in bank vaults applies with equal force to burglar-proof safes. The same high-grade materials are used and the same careful methods applied in the construction of even the smallest burglar-proof chest.

Burglar-proof safes are now made both of the laminated and also of the later solid manganese steel variety that are absolutely impervious to any known method of attack.

Coincident with the modern development of the safe and bank vault industry was that of the profession of the Bank Vault Engineer. The industry owes much of its progress to the work done by the pioneers of this profession William H. Hollar, John M. Mossman, Geo. L. Daman, E. A. Strauss, Frederick W. Holmes, Benjamin F. Tripp and George L. Remington.

The days when might was right have given place to the later days when right is mighty. The safe industry stands ready to protect your valuables not only against fire and the burglar but against organized mob violence as well.

Physico-Chemical Studies of Rubber. F. W. HINRICHSEN. (*Zeit. Angew. Chem.*, xxiii, 1345.)—The more recent contributions to the chemistry of rubber are summarized. The author regards the constitution of the hydrocarbon as being definitely settled by the researches of Harries, and refers to the possibility of synthetic production. The determination of the molecular weight of the substance present in the globules of the latex has given results which indicate that this substance is not the comparatively simple compound supposed by Weber, the molecular weight being about 3000. The rubber is undoubtedly present in the latex as a typical colloid. The recent work on the optical activity of the rubber resins and on vulcanization by sulphur chloride is referred to. The reaction in vulcanization appears to be a true chemical reaction, but in presence of moisture, it is accompanied by the formation of sulphur which is adsorbed by the rubber. The maximum addition of S_2Cl_2 is represented by the formula $(C_{10}H_{16})_2\ S_2Cl_2$.

Very Sensitive Selenium Cells. F. C. BROWN. (*Phys. Zeit.* xi, 481.)—Selenium cells of great sensitiveness can be prepared by using a mixture of two modifications of selenium, viz., the amorphous variety obtained by dissolving vitreous selenium in potassium cyanide and precipitating with hydrochloric acid and the red crys-

talline product prepared from the former by dissolving in carbon bisulphide and exposing the solution to direct sunlight. A mixture of 10 parts of the amorphous and 1 part of the crystalline selenium is rubbed to a paste with ether, pressed in a mould around wires of German silver, heated for 5 hours at 170°C. and then cooled. The resistance of the product shows great variations (5×10^7 to 1×10^{10} ohms in the dark). The ratio of the conductivity in the light to that in the dark, i.e. the sensitiveness, ranges from 30:1 to 300:1; and varies considerably with the temperature from 80:1 at 39°C. to 300:1 at 3°C.

Action of Ultra-Violet Rays on Certain Carbohydrates. H. BIERRY, V. HENRI, AND A. RANC. (*Comptes rendus*, cli, 316.)—Reducing substances are formed when solutions of certain polyoses (sucrose, gentianose, raffinose, etc.) and glucosides are exposed to ultra-violet rays. It is found that *d*-fructose, similarly treated, undergoes a molecular degradation, producing formaldehyde and carbon monoxide. Such a decomposition of this sugar has not been effected previously without the aid of ferments or chemical reagents.

Testing the Capacity of a Soil to Decompose Cellulose. H. R. CHRISTENSEN. (*Zent. Bakt. u. Parasiten k.*, xxvii, 449.)—Fifty grammes of dry soil are placed in a 300 c.c. Erlenmeyer flask so that it forms a level, loosely packed layer covering four-fifths of the bottom of the flask. On the uncovered part water is run in from a pipette until the soil is nearly saturated. Two strips of ash-free filter paper are laid on the wet soil. After some time the cellulose is attacked and is transformed to a viscous, gray slime or mucilage, in which the microbes are contained. When mould fungi effect the decomposition, a black coloration is produced, but there is no mucilage.

Metallic Thorium. CHAUVENET. (*Assoc. Franç. pour l'avancement des Sciences*, Aug., 1910.)—The author attempted to prepare metallic thorium free from oxide by using metallic lithium in place of sodium for reducing thorium chloride. By heating the mixture in an iron boat in a quartz tube from which air was carefully excluded, a product containing 96 to 96.6 per cent. of metallic thorium was obtained. This, however, contained 3.2 per cent. of thorium oxide which could not be removed. A purer product, 96 to 97 per cent. of metallic thorium, was prepared by heating thorium hydride (obtained by heating together thorium chloride and lithium hydride to 600° C.) in a vacuum of 10 mm. The metallic thorium thus obtained is black; it is not oxidized by air or pure oxygen at atmospheric pressure, but is oxidized by oxygen under pressure. It takes fire with a luminous flame in fused potassium chlorate. It combines with chlorine to form thorium chloride, $ThCl_4$, with the liberation of 339.43 calories.

THE SELECTION AND TREATMENT OF ALLOY STEELS FOR AUTOMOBILES.

BY

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(*Presented at the meeting of the Section of Mining and Metallurgy held Thursday, October 20, 1910.*)

[This paper treats of the various kinds of alloy steels and their applications in the automobile industry. Attention is called to the necessity of selecting steels which will do most efficiently the particular work for which they are intended.]

A POPULAR remark during the last few years has been to the effect that the steel business has advanced and changed rapidly and that the incentive is found in the manufacture of automobiles. This condition still continues and the evolution within the construction of the car itself is no less rapid. Design, materials, style and selling methods are all involved.

Curiously enough, it would seem at first glance, the choice of materials is involved in all of these four branches of the industry and not in the one or two as would seem natural.

The reasonable use of materials is to be the theme of this paper. Many considerations are involved in looking back to the beginning of the automobile industry and it seems necessary to do this in order that the evolution may be followed as far as materials are concerned.

At the beginning every faculty of designer and builder was focused on the production of an operative machine. Materials were disregarded so long as they would help build the vehicle and were obviously steel, brass, aluminum or wood. All were too busy to regard the quality. Generally speaking there was available from the stand-point of the automobile builder Bessemer steel, open-hearth steel and cast or crucible steel. Variations within these classes were regarded as unimportant and heat treatment was an unknown term: certainly only theoretical at the best and therefore useless to a practical man.

Now these same men have among them those who state that the heat treating department of the works is the most important

of all. This is not so with all yet; there are some who still balk at talk of critical points, recalescence, pyrometers and the like. The evolution is rapid however and this class will soon disappear.

After a year or two the cars operated very well; at least well enough to run long enough to break parts, crank shafts, axles and steering parts. Then a little attention was directed toward steel. There seemed to be no clear idea of a cure. If a steel part broke with an appearance of brittleness good old wrought iron was tried as a sure cure. If bending occurred tool steel was tried in some cases and medium carbons (0.50 per cent.) in others; it being understood that high carbons were stronger but brittle. The natural or annealed state was the only one known to the automobile industry at this time.

At about this time nickel steel was mentioned as a possibility. It had been used, or as some said "advertised as used" for bicycle construction. But generally it was regarded as something fancy and not worthy of the consideration of hard headed men. It was expensive, hard to work and no good anyway in the opinion of many.

So when alloys came along in earnest and were offered systematically by steel agents they had a hard time making any progress. The high prices quoted were laughed at. There seemed to be no chance that alloys would ever be given a fair trial. After some little time and persistence by the steel agent, alloy steels were tried and proven good even at 15 cents per pound. Some designs required alloy steels to stop breakage the result of small dimensions, sharp corners where fillets should be and similar mistakes. In this way the alloy, or perhaps the high quality carbon steel, had a chance to make good in a spectacular way. These instances helped the spread of high grade steels until now the pendulum has swung too far and alloys are used where they need not be and money is thereby wasted. There is indication of a notion that an alloy steel is a cure-all; and that if needed in one part that it must be a fine thing in all parts.

Unfortunately the art of heat treatment has not spread as fast as alloy steels have and many cases exist where very expensive steels have been put into cars in an annealed or forged condition; which is absolutely unreasonable. The alloy steel is no cure-all and must be used intelligently, if any compensation for increased cost is to be realized.

A case in point is found in an engine crank shaft. It is large for the duty. If it is made of an alloy treated up to 100,000 lbs. per sq. inch or more, when 60,000 lbs. would suffice there has been no gain to the automobile and there has been a money waste. It is not generally understood that a high elastic limit adds nothing to the stiffness or rigidity of a part. It does add to resistance to fatigue but with the case in point the shaft is over size and fatigue cannot take place in the absence of bending.

The same general condition applies to gears of all kinds. It is not the rule, by any means, that gears of smallest section are made of the strongest steels. This should be so and is so in one very marked case. On the other hand many very heavy gear sets, duty considered, contain steel of greatest strength and all out of proportion to necessity. This is unreasonable as it is obvious that strength should be a function of design. A bridge or a building is calculated to a nicety, as yet automobiles rarely are. Knowledge of steel is not yet sufficiently wide-spread. The history of the automobile is short and there has not been time enough to disseminate knowledge of so many special steels and special treatments. Then too an air of mystery regarding special steels and secret treatments has been fostered in some circles in such a way as to befog the issue and retard the spread of truth.

At the beginning of the automobile art the steel industry was old. Alloys and heat treatments were no mysteries to the steel metallurgist. Makers of armor plate, gun tubes, propeller shafts and other important specialties had been using many grades of steel and many treatments to meet peculiar needs. This knowledge had not and does not spread readily to makers of small arms, sewing-machines, bicycles or typewriters and they all need it to some extent.

Some reason for this is found in the "old fashioned" selling methods of many steel companies. Most salesmen are not furnished with accurate knowledge of the steels they sell or if they are they are forbidden to use such knowledge on possible customers. They use a line of argument that contains no metallurgical information and is too often far from the truth. There are large numbers constantly engaged in this way so it is no wonder that little real progress is made by aid of the salesman. Fancy names and fancy prices for common steel is their specialty.

It is a pleasure to feel that such methods are giving way to

others and better. The steel works engineer, metallurgist or chemist is now placed in contact with the consumer. His wants are learned and supplied without secrecy or mystery. The opportunities of change and improvement are pointed out and advance in the art will be rapid. As it is now there is buf little knowledge, among consumers, as to the relative importance of analysis and heat treatment or of the importance of casting, rolling, hammering and cold working of steels. Consequently many consumers are in doubt as to what to believe, the truth as expounded by the conservative metallurgist or the near truths about the special alloys of the salesman.

Before taking up the finer steels it is well to study the history of what preceded them in the automobile art.

At the outset carbon steels were mostly considered and known as machine steel. Such steel was available and cheap, or at least low in first cost. Such steel is not always cheap, as much of it tears in machining to such an extent that work is ruined or will not permit the cutting of a thread at all because of its softness. Such machine steel is of about the following composition. It is not strictly speaking machine steel but there is so much of it on the market, so called, that it must be recognized. Carbon 0.08 to 0.13 per cent., phosphorus 0.08 to 0.10 per cent., manganese 0.40 to 0.60 per cent. and sulphur 0.06 to 0.08 per cent.

Machine steel, so called, as found in steel warehouses is not all alike by any means. This lack of uniformity is discovered by the user whose judgment usually is that the steel is no good anyway and does not behave twice alike in the machine shop.

The best machine steel, then existing, in stock, was of about the following composition with carbon from 0.18 to 0.25 per cent., with other elements like the foregoing analysis. Such steel machines smoothly and cuts a keen thread. A slight increase in carbon coupled with the other elements given makes a very marked difference in machining quality. A third quality of machine steel found on the market at the time in question was between the other two in carbon contents and much higher in manganese, analyzing about as follows: carbon 0.12 to 0.18 per cent., phosphorus and sulphur about 0.08 per cent., and manganese from 0.60 to 0.90 per cent. The manganese contents made for smooth cutting and the steel was a good one for carriage axles, which must be machined very rapidly, and other similar uses.

These machine steels were all characteristic of Bessemer output and were put into the early automobiles. They answered the purpose until the machines began to wear fairly well and poor (weak) design developed. High carbons were tried and wrought-iron was tried all in a blind unreasoning way. Some troubles were cured but some could not be cured by any change of material known at the time. The details of design were such as to cause failure with any material. Failure was delayed but not prevented.

One grade of steel, common then and now, known as screw stock deserves notice, as it plays a more important part in automobile construction than it ought to. It is close to machine steel and is sometimes sold as such. The approximate analysis is as follows: carbon 0.08 to 0.12 per cent., phosphorus 0.12 to 0.18 per cent., manganese about 0.50 per cent., sulphur about 0.10 per cent. The dominant element, that makes for easy cutting, is phosphorus, which is twice normal for Bessemer steel. More steel of this quality than of any other composition, can be put through an automatic screw machine in a given time, and turn out a fine product. But the drawback is phosphorus, which causes brittleness in steel and makes it unsafe for automobile construction. Except in screws of no importance or parts carrying no load, it should not be used. Important screws are now made of alloy steels heat-treated. Connecting-rod and engine-base screws for example. The above screw stock after casehardening, as it often is, shows a coarse brittle grain even with the best of treatment. No hardened parts of this quality should be used.

At the present time little steel high in phosphorus finds its way into automobile construction. Basic Open Hearth steel is mostly used and this is uniformly below 0.04 per cent. in both phosphorus and sulphur.

This quality of steel in the vicinity of 0.10 per cent. carbon machines with the greatest difficulty, consequently a standard machine steel has been developed containing enough carbon and manganese to offset the softness. The analysis is as follows: carbon 0.20 to 0.30 per cent., phosphorus and sulphur not over 0.04 per cent., manganese 0.40 to 0.70 per cent.

This quality of machine steel handles well in every stage of manufacture and responds to heat treatment in a way that makes the product suitable for many parts of a car. This steel is a fine steel for the general run of drop forgings. It is suited for the

important members of low priced light cars, and for carbonized and hardened bevel and transmission gears in such cars as are of low power and generous gear design.

With the general use of basic open-hearth steel this type of machine steel is bound to be generally adopted. Its usefulness is very wide-spread and its cost as low as any open-hearth steel. The extra expense that is warranted is the care necessary to free from seams or other physical defects. This is done by the steel maker or the one who prepares the billets or bars for shipment. Freedom from seams insures a sound product at the finish of an expensive series of operations and is worth paying for.

Simple heat treatment will give an elastic limit per sq. inch of 60,000 lbs. This is the result of quenching at about 1500° F. in oil, then partially annealing at 800° or 900° F. Such strength is accompanied by good refinement of grain and corresponding toughness and capacity to resist shock and repeated alternate stress. The machine steels previously mentioned would not be safe under the foregoing treatment or any other; as refinement of grain does not take place to a satisfactory extent in the presence of so large a percentage of impurities.

Without a fine grain development in steel fatigue takes place very rapidly. In using this term " fatigue " the same phenomenon is in mind that is often referred to as crystallization. Cold crystallization does not take place. It is a different physical change and will be discussed later.

About the years 1893–1894 bicycle parts often failed (to quote) " while riding along the smoothest road." The fractures did not exhibit coarse crystals as a rule, particularly in cold-drawn spoke wire or tubing. But in every case there did exist an opportunity for concentration of strains, bending or vibration, at a limited section. These failures led to studies of fatigue conditions.

It was commonly thought by well trained mechanics that the softest toughest steels would resist longest under these conditions simply because of the tough quality. This was found to be not so. Tough and soft steel is weak steel having an elastic limit per sq. inch from 30,000 to 40,000 lbs. A good grade of forty (0.40 per cent.) carbon steel may have an elastic limit of 50,000 or 60,000 lbs. Such steels in an annealed condition were compared under such circumstances as to produce a fatigue break. The dead or actual load used in comparison was the same. This

load was chosen to produce a fibre stress nearly as great as the elastic limit of the weaker steel, say 25,000 lbs. per sq. inch (about 84 per cent.). This stress was only 50 per cent. of the elastic limit of the stronger steel. The weaker steel, soft and tough, broke quickly after 20,000 to 50,000 alternations of stress. The stronger steel looked upon as being brittle and hard, endured say 400,000 alternations of stress, an increase not in direct proportion to strength and quite contrary to the characteristic of toughness as measured by elongation. It is evident that the toughness was not the controlling element under fatigue conditions and that strength as indicated by elastic limit was an important factor with some other element not obvious, playing an important roll. Such an element was sought in the crystalline structure. Such structure is fairly indicated by transverse fracture for the purpose in hand. The fracture of the low-carbon tough steel is course grained with crystals presenting large cleavage planes. That of the higher carbon, brittle steel, showed a close grained structure with no crystals having cleavage planes of conspicuous size. That is, the steel that endured longer was strong and fine grained. These were the controlling elements.

It is for this object that all heat treating processes are practised—to produce greater strength and to refine the grain. The most reasonable steel to use in automobiles is that which will respond best to treatment or that will respond sufficiently for a given purpose, dimensions and duty considered. There is no reason in selecting a steel that will not respond somewhere in proportion to the cost of the operation; that is, the improvement must be material. Neither is it reasonable to select a steel at great cost that will respond to such an extent as to be way beyond the necessities of the case.

The treatment necessary to give a steel depends somewhat upon the physical condition of the steel as received by the consumer or user. For example, it is quite possible and often happens that bars of steel reach the manufacturer of automobile parts in a very coarsely crystallized state, this being due to the last forging or hammering operation prior to shipment by the steel mill. If this steel is to be used by the parts maker without further drop forging or other heating operations, the steel must receive a thorough annealing. In the absence of such annealing operation, which will reduce the coarse condition of it to a

properly refined condition, a single heat treatment will not produce the expected results.

If, on the other hand, the bar or billet is to be forged, then this coarse crystalline condition matters but little and the annealing must necessarily follow the forging operation and for the same reason; to guard against a possible condition of coarse crystallization which will not be refined by a single heat treatment.

Our steel makers would do well to learn whether or not the consumer of the steel is to again forge. If not, annealing should be the final operation at the steel works in all cases. Otherwise, steel of good quality may not perform as well as it should.

It is not always possible for the steel manufacturer to know whether or not steel is to be forged again and, in view of that fact, it is the habitual practice of some of the steel mills to anneal as a final operation. No harm is done if the steel is again forged, and if not forged the steel is found, by the user, to be uniform in machining qualities and well behaved under heat treatment. Uniformity of machining quality is of far more importance in the eyes of the mechanic than is fully appreciated by many steel companies. Many thoroughly good qualities and shipments of steels are complained of and perhaps condemned because of the presence of so-called hard spots and bad cutting qualities. The machine shop cannot be expected to know that it is not the composition of the steel that is at fault and the steel maker should guard against such complaints by the relatively inexpensive operation of annealing.

These remarks apply very strongly to tool steels that are to be shaped into expensive tools, to spring steels and to the higher carbon steels in general. They apply in a lesser degree to the lower carbon steels but nevertheless are of great importance.

Many machine steels are condemned because tools are rapidly dulled in machining them and the complaint is, as a rule, that they are too hard to cut. As a matter of fact they are too soft to cut smoothly. They tear and cling to the point or edge of a tool and the cutting operation becomes more or less of a rubbing operation which creates heat and dulls the tool by softening it. Proper annealing, suited to the carbon, will correct this fault, but the machine shop manager cannot be expected to know this and probably has no facilities for annealing or other heat treatments in many cases.

Take an engine crank for example. Other considerations than strength influence the design. It must have ample diameter to furnish adequate bearing surfaces. It must be rigid and stiff. No alloy can increase this latter quality. A steel with 60,000 lbs. elastic limit per sq. inch is quite strong enough to outlast the engine. One of 200,000 lbs. elastic limit would make no better crank shaft under the assumed conditions and would cost more at first cost, in forge, in machine-shop, and in heat treatment. This is a fair example of unreasonable use of alloy steel.

To return to qualities producing endurance under alternate stress. A drop forging as it comes from the dies is likely to be in a non-homogeneous condition as the result of the process and at the best, because finished at a relatively high temperature, is likely to possess a very coarse open grain. If intended for a vital part this grain must be refined. It may be perfectly done by proper heat treatment, and it is done habitually by careful operators. The result is a homogeneous piece of metal. No other character of steel is fit to enter the construction of an automobile where it is potentially possible of much harm or much good. Carbon steels should be so treated; alloy steels must be, if fair value for money spent is to be received.

Alloy steels of expensive variety have been put into cars without heat treatment, just to say they were used. An alloy steel not suitably treated, that is in an annealed or forged state, is little if any better than good open-hearth machine steel in an annealed condition. Its endurance under fatigue test is low. Its elastic limit is low, and its structure as indicated by transverse fracture is bad. Such use of alloy steel is unreasonable and the only additional value obtained for the excess paid as compared with carbon steel is an advertising value.

On the other hand alloy steels suitably chosen and heat-treated have extricated many an engineer from real trouble. A driving shaft, having 60,000 lbs. elastic limit, for example, may have proven weak with good carbon steel. Because of the design of connecting parts a change in dimensions is often practically impossible. A solution is easy with a good 0.30 carbon, 3.5 per cent. nickel steel treated to 90,000 lbs. per sq. inch elastic limit, or if necessary a chrome-nickel of high carbon treated to 150,000 lbs. elastic limit. Such applications of alloys are worth all they cost and are reasonable in every way.

It is the alloy steel that responds best of all steels to heat

treatment. Results are obtainable that are nothing short of wonderful. Only recently a tensile strength of 300,000 lbs. per sq. inch has been reached. Coupled with such strength, say 200,000 lbs. per sq. inch, very great ductility is obtainable as indicated by elongation and reduction of area at section of rupture. Too great stress cannot be laid on this last item. It is the best measure, in a tensile test, of the degree of refinement of grain attained by heat treatment. Reduction of area will be slight if the crystals or grains are large. If the grains are large as already stated, endurance under fatigue will be little and endurance is beyond argument the most valuable asset of an automobile subjected as it is to shock and vibration at all times, while in motion, and to an extent beyond any other mechanism.

Attention has been called to the relative endurance of 0.10 and 0.40 per cent. carbon steels under fatigue test. Under the same dead load a specimen of 0.30 per cent. carbon, 3.5 per cent. nickel heat-treated will endure several million alternations of a 25,000 lbs. per sq. inch fibre stress, and a specimen of 7.5 per cent. nickel has endured one hundred million without rupture with the fibre stress at about 50,000 lbs. per sq. inch. The tensile tests give no indication of any such difference in endurance unless it be in the reduction of area coupled with a high elastic limit. These figures are always large with good endurance. The reduction of area is a measure of fine grain, so it would seem that this quality may be the most influential in determining endurance.

There is good chance for theorizing and reasoning along this line. With the theory of cold crystallization set aside, a reasonable cause for breakage must be found. Steel may be considered as made up of crystals which interlace and adhere. If a test specimen were made up of crystals whose faces equalled the diameter of the specimen, there would be the exaggerated condition of all adhesion and no interlacing. One cleavage plane extending across the specimen. It is easy to conceive that the separation of surfaces once started would jump at once across the specimen and rupture would occur. There would be only adhesion to overcome. It is equally plain that were the same specimen made up of an infinite number of crystals, that a separation started at the periphery would meet with an interruption before being of finite size; after which a fresh start might recur at another point to meet with similar interruption. In this way

an infinite number of starts would be necessary to bring about rupture. In other words there would be no chance for a continuous fracture along any one line or surface, and rupture would be delayed indefinitely.

A fibred piece of steel endures better than one not fibred although both may be of very fine grain. It is easy to conceive that if "fibre" is all the name implies, that an incipient fracture formed in one fibre could not continue across the space between fibres and would thus stop. Wrought-iron breaks under fatigue as in an axle or shaft. The fracture always shows crystals. Is it not possible that a fatigue break can take place only where crystals exist, and that because crystals are at a given section, fracture takes place there?

It is easy to understand how a progressive fracture may proceed along the faces of a series of crystals as in the splitting of granite by means of wedges driven into a row of holes. It is not easy to conceive the splitting of good fibrous hickory or elm except with and along the fibre. Splitting across the fibre is impossible, there could be no continuous fracture and therefore no rupture.

A fatigue break has been described as "progressive intermolecular rupture." It would seem more probable to be "intercrystalline" inasmuch as the molecules, of a given composition, are doubtless all of a size, regardless of heat treatment or physical treatment. On this theory, heat treatment would cause no difference in behavior under fatigue; which would be contrary to fact.

Another phase of fatigue is, that such breaks rarely if ever occur unless strains concentrate at or near one plane or section. If strains be distributed as in a beam of uniform strength, fatigue does not occur. A generous fillet or a taper retards fatigue almost indefinitely. A sharp corner causes it to occur very quickly.

Design and material both play an important part, and the two must be considered simultaneously if good engineering is to be attained. If a design be adequate with poor material, it is folly to buy better. If design be suited for the best, then only such may be used otherwise bending and breaking will occur at once. These statements seem too simple for reiteration, but it is a sad fact that both simple truths are violated in automobile construction.

There is one form of heat treatment as old as the hills, that is little understood by many that have practised it longest, namely, "casehardening." It is easy to turn out coarse or fine grained product. The fine grained is desirable (as in good tool steel), the coarse grain is not, as in burned tool steel. Too few realize that a low grade steel after carbonizing is no longer low grade. It has had money spent on it to improve it and if the low carbon was pure steel; the high carbon exterior, the result of carbonizing, is pure high carbon steel; therefore, good tool steel and must be treated accordingly.

No tool dresser would heat tool steel in boxes for ten hours at a temperature of 1700° F., then quench in water at that temperature and expect a tool to do good work. Yet this is exactly what is done in many otherwise well regulated plants, and the steel is blamed if the parts so treated are brittle. So treated the crystals are large; the steel is brittle.

If used for ball or roller bearings, the polished surface is friable and crystals spawl out thus starting pits and fractures. Suitable refining treatment improves this condition and makes a success out of a possible failure.

In casehardened parts two qualities of metal are to be dealt with, and the best practise demands treatment that will refine both grades. The interior of two are the original carbon and the exterior a carbonized layer of a higher carbon. The refining temperature of the lower carbon is higher and one treatment must reach this. The other temperature, correct for the high carbon, will not undo the refinement of the lower carbon. Thus by two treatments both qualities are fully refined and the composit structure is a good one. Alloy steels are subject to the same laws, and it is only necessary to be acquainted with the critical points of the various compositions to get the best results.

Transmission gears and main drive bevel gears are successfully made of carbonized steel, both carbon and alloy. The quality selected must be referred to design and duty. The duty of constant mesh gears running in oil is relatively easy if the dimensions be generous. The duty of clashing transmission gears is never easy and may be awful with a dragging clutch or careless manipulation by the car driver, and with clashing taking place under loaded or partially loaded conditions.

With equally good design the bevel driving gears do not need the same or as good steel as the transmission gears. It is com-

mon and good practice to make the large bevel gear of good carbon steel and the driving pinion meshing with it of an alloy steel.

The character of the treatment and resulting condition of the steel is of vastly more importance than the composition of the steel used. The best of alloy steel may be so handled in treating as to produce a weak and inferior part. Similarly by the best of treatment good open-hearth machine steel may be so well handled as to make a most excellent main drive pinion or other part.

It is true that the best must be produced for a few designs, but such are much in the minority at this time. There has been very little real close designing as yet. Empirical knowledge and data as to available materials are not yet exact. The art of heat-treating is not uniform and wide-spread among producers of automobile parts. A liberal margin of safety against uncertainty and non-uniformity is still the rule.

There is one practice in vogue among purchasers of alloy steels that does not seem to be founded on good reason. It is that physical requirements are specified in face of the fact that the steel is to be forged and heat-treated before being used in a car. Its final condition may bear no relation to its purchased condition. It may be carbonized for example. If steel be purchased on chemical analysis, the control is sufficient. With a known composition heat treatment may be intelligently directed without reference to original tension test characteristics.

If to be used as purchased, the matter is different and physical characteristics must be known. Elastic limit, reduction of area, elongation and tensile strength, in the order named, are desirable. If these physical tests be demanded then complete chemical analysis must not be. The steel manufacturer cannot produce if tied hand and foot. It is proper to specify chemical analysis as to impurity, that is phosphorus and sulphur, and also as to the dominant elements; nickel, chrome-nickel and so on. Even in these elements, manufacturing tolerances must be allowed. The practice of limiting all elements and coupled with physical requirements is wrong and often leads to the absurd situation of specifying an impossibility.

Even at the best, with the one writing the specifications knowing exactly what has been the practice in one steel works; it is not certain that in another works the result would be quite

the same. Some works use melting processes, casting methods, and forging methods that may easily modify physical characteristics as compared with practices in other works.

With a given quality of automobile in view, the number of grades of steel necessary to construct it is few, namely, a good all-around forging steel, a steel of slightly better quality to be used for gears, a spring steel and a steel suited for the pressed sheet-steel portions of it.

These steels, properly handled and heat-treated, each part for its peculiar duty, will produce a car of very high grade so far as the steel portions are concerned.

The car of extreme design, racing or otherwise, one that has been designed to strip off the last pound of weight, must be handled differently. Such a car is the exception and must be treated accordingly.

If an order be accepted at all under such unfair restrictions, it must be at an advanced price to cover probable difficulties. This simple fact is so well known to the steel producer that it is apparently absurd to state it, but it is not well known by the steel consumer and needs repeating for their benefit.

To sum up, the attempt has been made to indicate that alloy steel is better than plain carbon steel, that is, stronger and more enduring; that the design of some cars is such as to necessitate the use of the strongest alloy steel and that the design of others is such that an alloy steel is superfluous and money wasted.

That steel that is good for one purpose is bad for another and really that the term "good steel" is meaningless unless it be understood "for what." Pure steel, meaning freedom from impurities, means something always. It insures that such steel will give "good" results if the composition is suitable for a purpose and if the steel be treated to develop proper physical characteristics for the duty to be performed. Several steels (compositions), may be available that will perform a given function perfectly if properly selected and treated. No consumer need be tied to one maker, one composition nor one method of treatment. Several of each are always at hand that will give satisfaction. Reasonable use of steels can only be reached along lines as broad as this.

PROBLEMS IN CHEMICAL INDUSTRY.

BY

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(*Read at the meeting of the Section of Physics and Chemistry held Thursday, November 3, 1910.*)

[The writer discusses the difficulties which arise when an attempt is made to apply on a commercial scale the results obtained from laboratory experiments. He is of the opinion that the chemist is best fitted to overcome these difficulties who combines with the scientific mind a certain amount of common sense.]

INDUSTRIAL chemists may well pride themselves upon being engaged in one of the most important and useful branches of the so-called sciences of the present day, and one that requires, in a certain sense, more science in the solution of its problems, than any other.

The question has often occurred to me, however, to what extent is chemistry a science, and is the solution of its problems a purely scientific work. After analyzing the subject carefully, I am lead to venture the statement that chemistry, as we understand it, is not a science, in the strict sense of the term, although it cannot be denied that the enormous advance that has been made in the field of chemistry during the past century, is due in a measure at least, to what is known as scientific investigation and the application of scientific principles. Much of the success, however, if not the largest part of it, is due to the application of what is known as common sense, in contradistinction to so-called science.

Some one has defined science as "organized common sense," and this definition, to a certain extent, is true, but the common sense that I refer to is that which is, so to speak, unorganized, and follows no given rule, but occasionally arrives at a conclusion in a problem, without any definite reason, except it be on the plea, that all great discoveries are the result of accident.

Taking the definition of science as organized common sense, or to use another expression, as systematized facts, this definition

also implies the further use of knowledge thus systematized, and the distinction between a scientific and an unscientific mind, is that the former adheres to a system and applies it, or attempts to apply it to various problems, while the unscientific mind follows no definite line of action, and arrives at results by accident or by good luck at guessing.

On the basis of the above definition of the term science and what it implies, it is evident that the most perfect science will be that in which the systematizing of facts is most complete, and the degree of perfection will be determined by the extent to which the system can be applied and followed. A perfect system is one that is based on a well-defined principle, in which every step is an application of this principle. In this respect it will be found that mathematics is the most perfect system, for here the system is so perfect that its principle can be applied and followed to an unlimited extent. The conclusions reached are absolute and hold good for all time and under all conditions. This is pure mathematics and it is pure science.

In the applied sciences, however, the systematizing of facts is not so complete, and in consequence the systems are not perfect, and can therefore be followed only to a limited extent. The avowed principle of the system and the conclusions reached do not agree, although in some cases the disagreement may be so slight as to be insignificant. Mathematical astronomy affords an example of the most perfect system of applied science, for here, while the systematizing of facts is not absolutely perfect, and consequently the conclusions are not absolute, they are so nearly perfect that the conclusions reached may hold good for thousands of years to come. The variations may be so slight as to be almost infinitesimal, but as long as the conclusions are not absolute, the system is not perfect. In the final analysis the scientific mind fails, and the problem is solved by the unscientific mind, which makes a guess at the result by striking an average.

The absoluteness of pure mathematics as a pure science, and the approximate absoluteness of the science of astronomy, may be explained by the fact that one factor only is taken into consideration in mathematics, namely, that of the relation between objects expressed in symbols, the physical properties of which are entirely ignored, while in astronomy, it is the relation between planetary bodies, the physical and chemical properties of which, however

much they may affect the final results, are also practically, if not entirely, ignored.

In fact, as we proceed to explain science in general on this basis, and apply the explanation to the so-called sciences that involve factors whose physical properties must be taken into consideration, it will be found, as the number of factors increases, that the systematizing process becomes more difficult and impossible, while the purity and accuracy of the science decreases accordingly. This will be observed as we pass from astronomy, where the factor is only one, or practically one, to mechanics, physics, chemistry, geology, biology, psychology, etc., the factors of which increase, while their accuracy as sciences decreases in the order named, until we reach sociology and theology, where the factors, consisting entirely of the vagaries of the human mind, become so numerous and antagonistic, that any systematizing whatever is practically impossible, and to these the term science has consequently no application.

It will thus be seen that the term science when applied to the various concrete sciences, has a very limited application, depending upon the number and complexity of the factors involved, and the pursuit of any of the so-called sciences in which the factors become numerous, would soon come to a stand-still, if it did not include the assistance of the unscientific mind; because a multiplicity of factors gives rise to problems, the solution of which is accomplished not so much by science as by empiricism. The tendency of the scientific mind, trained as it is, to look at problems along well-defined lines, in obedience to some system or law, is to ignore conditions and suggestions that do not seem to conform to these laws, with the result that valuable facts are often overlooked. The tendency of the unscientific or practical mind is to go to the other extreme, and ignore laws and systems, and try any suggestion that chances to come along, with the result that while much valuable time and labor may be lost, the loss is fully compensated by a few valuable successes.

I think it is safe to say that it is to the unscientific or practical mind that we are indebted for discoveries in the field of science, for it is only as we deviate from the well-known and familiar paths laid down by the scientific mind, that we stumble upon and discover new facts, and while the unscientific mind stands astonished and at a loss to know what to do with the dis-

covery, it remains for the scientific mind to lay hold of the novelty, and find a place for it in some general system of things. It has been said that the difference between a discoverer and an inventor, is that the discoverer is one who uncovers some new thing which he cannot make use of for lack of knowledge, while the inventor is one who takes the novelty, and by use of his accumulated knowledge, is able to recognize and make use of it, by means of a so-called invention.

While science may be defined as the systematizing of facts, the ultimate object of the system is to arrive at or hypothecate, if necessary, some law that will not only satisfactorily explain the facts, but will also enable us to deduce from the law new facts, or in other words to predict new facts or events. Pure mathematics affords the best example of this ability to predict or make deductions, for its deductions are without limit. Mathematical astronomy affords the next best example, for its deductions, or predictions, relating to the position of planetary bodies, can be made thousands of years in advance.

Prediction may therefore be considered a criterion of pure science, and the purity of a so-called science may be measured by its ability to predict, and this depends upon the absoluteness of the law or principle upon which the predictions or deductions are made, for where there is more than one principle involved, the deductions must be more or less antagonistic. In pure mathematics there is but one law or principle,—"The whole equals the sum of its parts," and although there may be many corollaries to this law, the deductions are absolute and there can be no antagonism. In astronomy also, there is practically but one law or principle, the law of gravitation, expressed in mathematical terms, and the deductions or predictions therefrom are almost, if not quite absolute. The absoluteness of a principle implies absolute consistency of its application, for any deviation therefrom must necessarily involve the application of other principles. Pure science therefore is a system that involves an absolute principle and absolute consistency in its application.

Now with this understanding of what constitutes pure science, let us turn to the so-called science of chemistry—does it involve but one law or principle, and do we or can we consistently apply this law to the various problems encountered?

Up to the time of Dalton it is well known that the study of

chemistry was in a more or less chaotic condition, but after Dalton annunciated his so-called "Atomic Theory," and the same was generally accepted as a working basis, if not as a fundamental law of nature, chemistry became known as a science. Why? Because here was a fundamental law or principle that was considered absolute, and could be consistently applied, with the result that absolute deductions could be made upon the strength of it, and new facts or events could be predicted. Thus we can predict that if the atomic proportions of Cl and H are as 35 to 1, then 35 parts of Cl combined with 1 part of H will produce 36 parts of HCl whether we take grains, pounds or tons of the materials. We can predict that whatever quantities we can combine in chemical affinity, we shall find the same quantities in the resulting compound, and in doing so we have predicted a new fact or law known as the law of the "Conservation of Matter." By a combination of various laws deduced from the fundamental law, we get the law known as the "Periodic Law," from which we can predict new and heretofore unknown elements.

In so far therefore as the law of the Atomic Theory is applied in making deductions therefrom, and in predicting new facts, to that extent, we may honestly say that chemistry is a pure science. But in chemical investigation, in research work, and in chemical industry, etc., do we or can we apply this law to existing conditions and to the problems that confront us? Working on a small scale, where the only object is the demonstration of the law, the application may so closely approximate the law, as to warrant us in saying, on the basis of probability, that the law is applicable, but when the law is applied on a larger scale, as must be the case in chemical industry, its limitations become very apparent. It would be difficult if not impossible to mention a single instance, where it is not necessary to alter calculations based upon deductions from the law, in order to obtain satisfactory results. Even the atomic weights, upon the application of which the law is based, are not absolute, and it is therefore self-evident that any deductions therefrom cannot be absolute. These slight inaccuracies experienced when working on a small scale are conveniently attributed to "experimental error," but in operations on a larger scale, particularly in chemical industry, the discrepancies are very marked. Just one example will suffice to illustrate the failure of the law in its application—the manufacture of HNO_3 for in-

stance. The law would require the combination of 172 parts of $NaNO_3$ with 98 parts of H_2SO_4, and on a very small scale in the laboratory, these proportions might give results approximately accurate, but on a large scale using cwts. or tons, these proportions will not give accurate results by any means. That is not to say that the combination takes place in any other proportion than those laid down in the law, but that the proportions required to produce the calculated results, are not the same. Here the deductions of the scientific mind fail, and the unscientific minds steps in and by experimenting and guessing, finally discovers that 95 parts of $NaNO_3$ instead of 172 must be combined with 98 parts of H_2SO_4 to produce satisfactory results. The proportions thus determined upon, may then be accepted, to a certain extent, as a working basis for the use of the so-called scientific mind in working out future problems of a similar character.

Here we see an illustration of the fact above referred to, that discoveries are made by the unscientific or practical mind, while the scientific mind endeavors to systematize the discoveries and thereby formulate laws for future use. Both qualities are generally combined in the same individual in varying degrees and are essential for success in any line of work, for discoveries, unless they can be formulated into some system from which we can make deductions, are useless, while on the other hand deductions alone from a supposed unchangeable law, would soon become obsolete, by reason of its limitations, which are eventually revealed by new discoveries. If we possessed a universal law, deductions therefrom would be without limit, and discoveries which are now made by accident, would appear as a process of evolution. This is the case with pure mathematics in which there are no discoveries, for each new fact is the result of a process of deduction or evolution.

The principle of mathematics, however, as it is generally understood, is not a universal law, and although it is universally applied in all scientific work, it must be remembered that there are other factors that enter into all problems, each of which involves separate and distinct principles, producing in the end an anomalous condition, for where more than one principle is involved, there must necessarily cease to be a principle. In pure science, as for instance pure mathematics, there is but one principle involved, and its application to symbols that have no in-

trinsic value involves no complex condition, but in the concrete sciences, we have, besides the mathematical factor, other factors, principally physical, chemical, mechanical, and economial, to say nothing of the temperamental known as the " personal equation," all of which render the condition very complex, and the application of an absolute law, unless it be universal, impossible. This is of an absolute law, unless it be universal, impossible. This is particularly the case in connection with our so-called science of chemistry, for the application of its principles involves all of the above extraneous factors, and although they may be reduced to a minimum by the use of delicately adjusted appliances in connection with investigation work, they are always present to interfere with the complete application of the principle.

The question, therefore, " Is chemistry a science? " if we answer it on the basis of the definition of science as " organized common sense," by which we mean a system involving an absolute principle from which we can make absolute deduction, must be answered in the negative, for as we have seen, our deductions at best are only approximate, and in the most important branch of chemical work, industrial chemistry, its application is more or less a total failure. While it may be true that chemistry acquired the distinction of being called a science after the acceptance of Dalton's atomic theory as a working basis, it cannot be claimed that the enormous advance since made in the field of chemistry is due to the application of this theory, since in practical work we do not actually apply it at all. Advancement is due rather to the inspiration that this theory affords, by establishing a definite goal towards which concerted action may be directed, for it is concerted action and unity of purpose among workers along any particular line, that produces results.

That chemistry is not a pure science, does not, however, imply that it is to be deposed from its position of importance among other so-called sciences, for the same condition applies to them all, with the result that we have no real science except pure mathematics. Pure mathematics, however, limited as it is to symbols only, would be useless if it had no application to concrete things in connection with the other so-called sciences, and as this application is not perfect, owing to other factors present, we must conclude that there is no such thing as a perfect science defined as " organized common sense."

To escape from this apparent absurdity, we are compelled to change our definition of the term science, and devise a definition that will apply to existing conditions. Instead of defining science as "organized common sense," we might define it as "practical common sense," or as Prof. James might call it, "pragmatic" common sense, that is to say, the sense that makes use of anything that works. All sense is common sense, and the so-called organized common sense or science is judged, not by the degree of perfection of its system, however necessary perfection may be as a criterion of pure science, but rather, is it judged by practical consideration, by results.

Human nature is practical if it is anything, and a theory, no matter how profound it may be, even if it be a theory of life, has little interest for us if it is not practical. When a new theory is propounded, our first question is not, is the theory true, but, will it work, will it "deliver the goods"; if not, we have no use for it. We judge a theory, or system or any line of work, solely by practical considerations, and these practical considerations are not academic but humanistic, not scholarly attainments, but things that add to the happiness and comfort of mankind.

Human nature looks for immediate returns, and of all lines of work, can there be found one that gives for labor expended more satisfactory returns than that which is included under the name of chemistry. It is ostensibly based on a fundamental principle, and although the results may not accord with the principle, the results are, nevertheless, approximately what we are looking for, which is achievement, and even if incomplete, we are satisfied to call it a science. If its field of operations were confined to purely scientific work, where the only object is the relations between hypothetical atoms, its usefulness would be so limited, that its work would be no more productive of happiness than astronomy, which deals with the far distant planets, or the study of metophysics, that deals with things transcendental.

In fact the field of operations open to chemistry is unlimited, and there is no important line of practical work, in which mankind is interested, that is not in some way related to chemistry. On the other hand, the field of practical chemistry is not limited to so-called chemical relations, but includes within its applications many conditions that are not strictly speaking chemical at all, but mechanical, physical, geological, biological and even psycho-

logical. From a practical point of view we might say that chemistry is the science of all sciences, for it seems to include them all in one great whole. From determining the elements of the stars, down to analyzing our foods; from steel making to farming, chemistry is an important factor, without the assistance of which no industry can hope to succeed. Consequently its problems, which we started out to discuss, are of a most varied character, and their solution requires not only a knowledge of chemistry, but a thorough knowledge of all the other concrete sciences combined, and most of all an appreciation of the fact that success is counted not by the profoundness of a theory, but by practical attainments. Chemistry as a science, is as simple in its operations as the multiplication table, and involves no greater problems because its application is confined to symbols, that give rise to no counteracting conditions. Real problems arise when application is made to concrete things, that involve not only chemical conditions, but physical, mechanical, economical, temperamental, etc. Temperature, concentration, and so-called "mass action," form, size and construction of implements and utensils employed are all factors that must be harmonized and systematized, and this harmonizing process is what constitutes the problems of chemistry, problems that no scientific mind alone, much less, a purely chemical mind can solve. They are solved only by the broad, common sense, "pragmatic" mind, that is fortified with a knowledge of things in general, and often by the mind that boasts of no knowledge whatever, for as is sometimes the case, problems are solved by an ignorant mind, because unhampered and unprejudiced by preconceived laws, whose supposed fixedness often interferes with freedom of thought.

Just where to draw the line that distinguishes a chemist from another worker, is a difficult, if not impossible task, for if we define a chemist, as one who is engaged in solving problems in the field covered by chemistry, an industrial plant, for instance, then we must include every individual connected with the plant, from the officers down to the common laborer, for each, in his own sphere, is engaged in working out some problem connected with the industry. Consequently, a chemist, an industrial chemist in particular, and all chemists are supposed to be industrial in some capacity, is one whose occupation is that of solving problems arising primarily out of the chemical changes that are

constantly taking place in the material universe, but which ultimately embrace every condition that contributes to the material happiness and comfort of mankind. In fact his occupation is philosophical rather than scientific, for instead of looking at things from a scientific point of view, that is from a fixed and limited principle, he learns to look at them from all points of view, which is the philosophical view.

It has been said that "to gain an education is to cultivate an attitude of mind," that is to learn not merely to look at things, but to learn how to look at them. To merely look at things, is to look at them from one point of view, which results in narrow-mindedness, prejudice and bigotry, while the philosophical view cultivates a broad-minded, altruistic attitude of mind, and is productive of the greatest success and the greatest good to mankind.

This is a point that might well be impressed upon chemical students, lest they become deluded with the idea, gathered from their study of the theory of chemistry, that problems can be solved by the application of fixed principles and unchangeable laws, unconscious of the fact that their solution is in the end accomplished by adjusting and harmonizing conditions that are antagonistic and incompatible with any fixed principle that may be laid down in a text-book. Instructors in the natural sciences are too prone to impress upon their scholars the absoluteness of the laws of nature, without taking the necessary precaution of drawing a distinction between theory and practice, between science as organized common sense, and science as practical common sense. The most successful chemist is the one who combines a well-balanced amount of both the scientific and the practical mind, for the problems that will confront him require for their solution the broadest possible attitude of mind. Even those who have had many years of experience, are sometimes liable to be too scientific and to rely too much upon scientific deductions, as for instance when we have worked out some method to approximate perfection on a small scale and then make an attempt to apply it on a larger scale, only to meet with failure and financial loss, because some unforseen factor has arisen that interferes with the operation.

THE AIR-BRAKE AS RELATED TO PROGRESS IN LOCOMOTION.

BY

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(*Presented at the meeting of the Mechanical and Engineering Section, Thursday, November 17, 1910.*)

GENERAL AND HISTORICAL.

EVERY moving body is capable, by virtue of its motion, of doing an amount of work before its motion can be diminished or stopped, which is directly proportional to the weight of the body and to the square of the speed at which it is moving. In the case of a vehicle, means must be provided which will permit this work to be done harmlessly and in a proper and predetermined manner. Otherwise the element of danger involved increases so rapidly with the weight and speed of the vehicle that locomotion, except in its most primitive stages, is prohibitive. The development of locomotion and consequently of transportation is, therefore, dependent in no small degree upon a like or even superior progress in the art of controlling vehicles in motion.

The laws according to which this art progresses can be determined only by following the successive developments which have been made in train control apparatus. This will be treated briefly in what follows, dealing primarily with the principles upon which such apparatus must operate, the methods, both theoretical and practical, by which these principles have been and are being applied to the problem in hand, and the fundamental conditions of service which fix the requirements that must be satisfied by a reliable and practicable device of this character.

PRIMITIVE VEHICLE BRAKES.—Knowing that the ancients travelled extensively, and that the great empires of history moved large armies over the then-known world, accompanied by trains of baggage wagons and war machines, it is natural

to suppose that the necessity for retarding those vehicles must have been plainly manifested. But as a matter of fact, the first suggestion of this necessity by the use of a practical mechanism designed for the purpose does not appear to have been more than 250 to 300 years ago. The primitive carts and wagons which were used in agricultural work, and in connection with the transportation of baggage and supplies for armies, were of such construction that the natural resistance to rotation of their wheels was quite sufficient to bring them to a stop upon ordinary roads; and in cases of steep grades it was always easy to chain a log or stone (Fig. 1) to the back of the wagon, so that by dragging it over the ground the speed of the vehicle was checked.

Indeed, to find the time when the question of braking first came into prominence, it is necessary to go no further back than the period when highways became sufficiently well made and maintained as to admit of a heavy vehicle being drawn over them at comparatively high speed.

A remarkable adherence to one basic combination of elemental parts, of the same general character and function, is to be observed in even the earliest types of brake apparatus. This extends from the simplest primitive forms through the entire progress of the art until they are found to-day, associated, it is true, with great specialization and complexity of detail, but still having essentially the same fundamental components.

This is natural, because, as the moving vehicle must be controlled by self-contained apparatus, it was first necessary to devise means whereby a source of energy or pressure, located on the vehicle, might be made to generate retarding force, opposed to the motion of the vehicle.

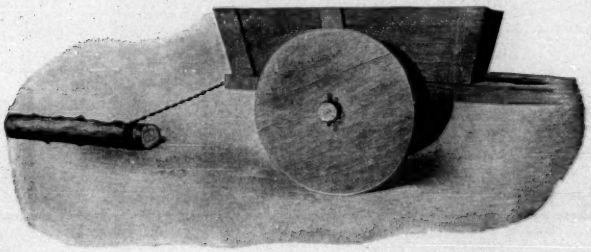
It is easy to see that the revolving wheels and axles offer the convenient and practicable opportunity required, and, consequently, it is not surprising to find that practically all brake devices, no matter how widely diversified in details, have one feature in common. This consists of a block or brake-shoe, as it is called, so located that it may be pressed against the wheel tread with more or less force as may be necessary. This develops a frictional force or pull between the relatively stationary shoe and the revolving wheel which, so long as it does not exceed the "adhesion" of the wheel to the rail or roadway

on which it rolls, tends to retard and finally stop the motion of the wheel and thereby of the vehicle itself.

It can be proved by experiment that the "adhesion" of a wheel to a rail while rolling (static or, more properly, rolling friction) is greater than the frictional force at this point when the wheel is sliding (kinetic friction). Therefore, the maximum retardation on the vehicle as a whole is obtained when the brake-shoe pressure is such as to produce a frictional force at the shoe nearly but not quite sufficient to cause the wheel to slide. This explains why wheel sliding must be avoided for theoretical as well as practical reasons.

EARLY RAILWAY BRAKES.—One of the earliest and simplest

FIG. 1.



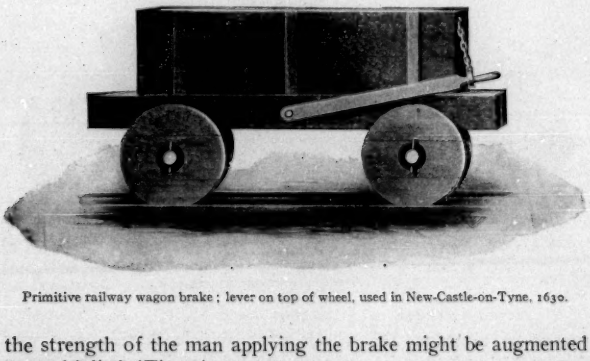
The drag.

means of retarding the wheels of a vehicle in this way was forced by a change in existing conditions, just as the many subsequent changes in methods of locomotion have been responsible for the perfection of the brake as we know it today. About the year 1630 an enterprising mine owner at Newcastle-on-Tyne, finding the roads between his mine and the river so bad as to seriously interfere with the hauling of coal, conceived the idea of laying wooden rails in the road and running his cars thereon. The tractive effort of these cars was thereby so much decreased that the necessity of some contrivance to check their speed was at once apparent and brought out simple forms of brakes. One of these forms consisted of a metal-tipped beam which was fast-

ened to the frame of the car in such a way as to scrape along in the ground at the side of the track. Another form was a simple lever pivoted to the side, near the centre of the car, and ordinarily held up by a chain, which, when desired for use, could be liberated and pressed by hand or foot against the top of the wheel, as shown in Fig. 2.

Many other simple devices of like nature were adopted by such rail- or tram-roads as then existed, which require mention only to point out that all made use of a block or shoe forced against the tread of the wheel either directly, or through the medium of some simple combination of rods and levers, whereby

FIG. 2.

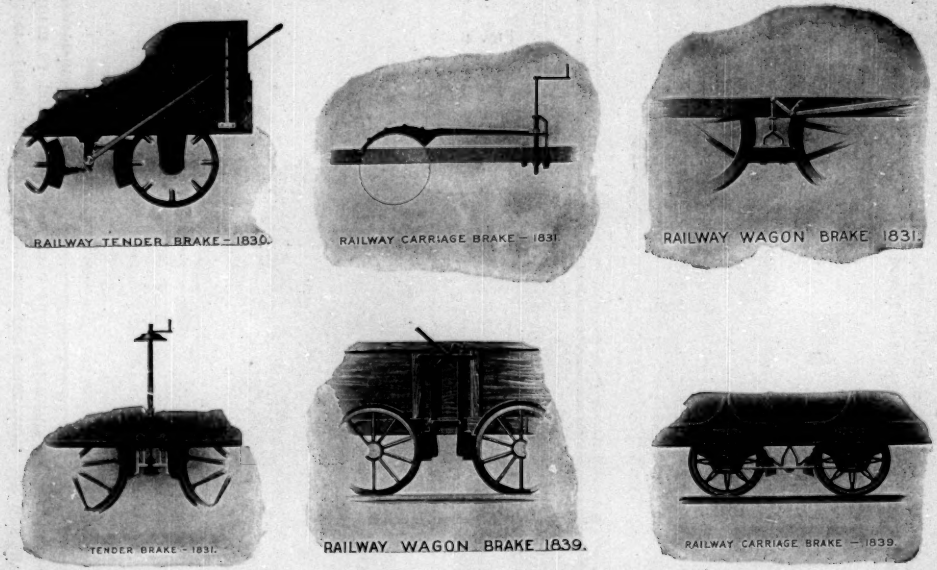


Primitive railway wagon brake; lever on top of wheel, used in New-Castle-on-Tyne, 1630.

the strength of the man applying the brake might be augmented or multiplied (Fig. 3).

THE STEAM-BRAKE.—As the speeds on these roads were generally quite low and the cars small enough to be drawn by draught animals, such devices served all practical purposes until the inauguration of a new order of things, by the advent of the steam locomotive. With the speeds and weights of cars which then had to be reckoned with it soon became evident that something better than a manually operated brake was needed. In 1833 Stevenson patented his steam-brake (Fig. 4), in which steam pressure, acting on a movable piston, was made to take the place of the hand-operated mechanism by which the force was applied through a system of rods, multiplying

FIG. 3.


RAILWAY TENDER BRAKE – 1830.
RAILWAY CARRIAGE BRAKE – 1831.
RAILWAY WAGON BRAKE 1831.
TENDER BRAKE – 1831.
RAILWAY WAGON BRAKE 1839.
RAILWAY CARRIAGE BRAKE – 1839.

Simple and early types of hand-brakes.

levers (and cams in this case) to the brake-shoe. In this first form of power-brake we have all the elements of a complete power-brake, viz.:

1. Source of power—steam.

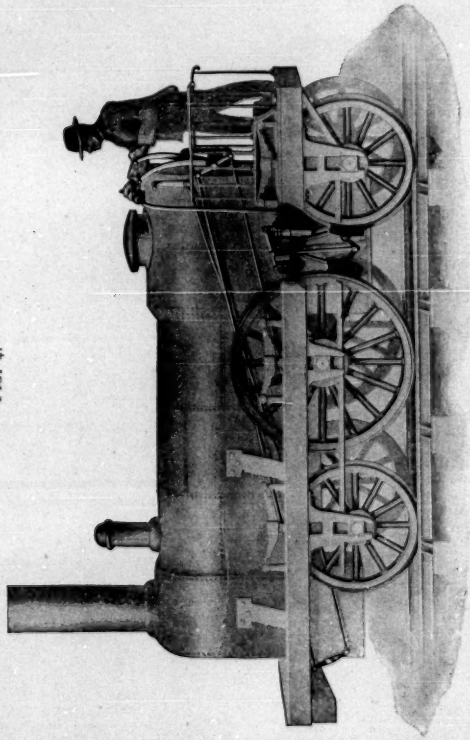


FIG. 4. Stevenson's steam locomotive brake.

2. Means whereby this power may be made to act upon the rods and levers of the brake rigging proper—a "brake"-cylinder with movable piston and rod.

3. Connecting rods and multiplying levers to transmit and

increase the pressure exerted on the brake piston—called the foundation brake-gear.

4. Means for transmitting the force exerted through the foundation brake-gear to the wheels as retarding force or "pull"—this being the function of the brake-shoes as already explained.

In the case of the cars, the hand-operated brake, with various forms of foundation brake-gear, met all practical requirements for some time, though a general realization of the necessity for some form of power-brakes is attested by the fact that during the first 70 years of the Nineteenth Century about 650 patents were granted in England for various kinds of brakes for railroad service.

PNEUMATIC BRAKE.

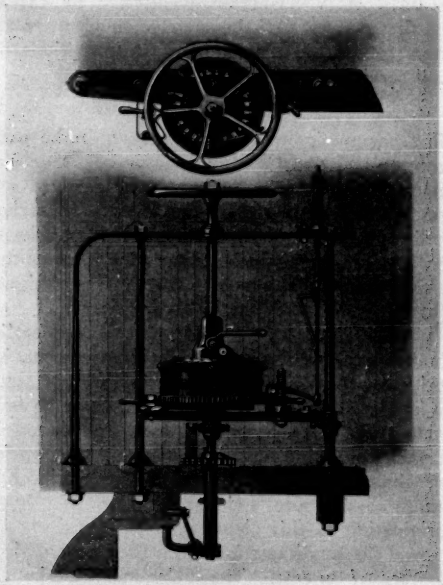
The first pneumatic-brake was a vacuum-brake patented by James Nasmyth and Charles May in 1844. In 1848 Samuel C. Lister patented an air-brake having an axle-driven pump and suitable reservoir to be placed on the "Guard's Carriage," and suitable cylinder, pipe, and connections on the various cars to constitute a straight-air equipment much the same as that which followed many years after, except that it was designed to be operated by the guard and not by the engineer.

CONTINUOUS TRAIN-BRAKE.—Of course, the earlier types of hand-brakes underwent considerable improvement, but while the majority of passenger, as well as freight cars, were braked by hand, as more and heavier cars came to be handled in the same train, the necessity for a "continuous" brake or one capable of being put in action on the various cars comprising the train, at the will of the engineer himself, became more and more evident. Some of the various systems originating in this country were extensively tried and seemed to meet the conditions for which they were designed with various degrees of success. The "Creamer" brake (Fig. 5), which was brought into use in 1853, consisted of a large spiral spring attached to the brake-staff, at the end of the car, and which was wound up by the brakeman immediately after leaving a station. Attached to the mechanism was a cord which ran through the train to the engineer's cab, and the brake was so designed that when the engineer pulled the cord, the coil springs on each vehicle were released and these at once wound up chains

leading to the foundation brake-gear, thereby bringing the brake-shoes against the wheels.

The "Loughridge Chain-Brake" (Fig. 6), which came into use in 1855, consisted of a system of rods and chains continuously connected throughout the train, as follows: On each vehicle were two pairs of small pulleys, each pair sliding toward the

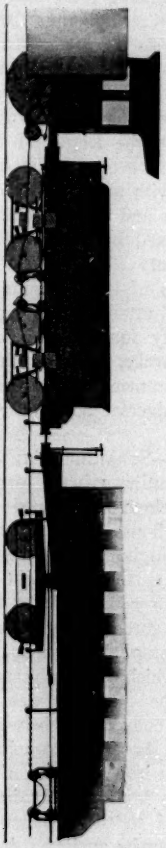
FIG. 5.



Creamer brake, 1853.

other upon an iron framework, but held apart by a spring; to each pair was connected a top rod leading to the foundation brake-gear. Upon the engine was placed a drum connected by a worm and gear to a small friction wheel; when a lever in the engineer's cab was pulled this friction wheel was brought into contact with the periphery of one of the driving-wheels,

thereby causing the drum to wind up the chain and shorten its length throughout the train; in so doing the pulleys upon



Loughridge chain-brake, 1855.

FIG. 6.

each vehicle were brought closer together, thereby applying the brakes.

In addition to the above, various forms of continuous brakes, other than air-brakes, were tried to a greater or less extent from time to time. Among these may be mentioned the Smith Vacuum-Brake, the Westinghouse Vacuum-Brake, the Eames Vacuum-Brake, the Fay Mechanical-Brake, the Clark & Webb Chain-Brake, the Barker Hydraulic-Brake, the American Buffer-Brake, the Widdifield & Button Friction Buffer-Brake, the Rote Buffer-Brake, the Carpenter Electric Air-Brake, and the Card Electric-Brake. From the length of this list it will be seen that to give an adequate description of these various systems would be to occupy with matter of purely historical or curious interest, valuable space and the time of the reader which promise already to be overtaxed by the demands of modern practice and recent development.

While these types of brakes were the result of much ingenuity and skill, and attained to a degree of success sufficient to prove the necessity for, and advantage of a reliable and efficient continuous brake, none of them satisfied enough of the fundamental requirements of a practicable, continuous brake to result in their universal acceptance as a standard in this country.

THE AIR-BRAKE—STRAIGHT AIR TYPE.—The first steps of the complete solution of the problem were taken, and a new line of development opened up, by the genius of Mr. George Westinghouse, who, in 1869 took out his first patents for the Westinghouse Non-Automatic Air-Brake, since generally designated as the "Straight Air-Brake."

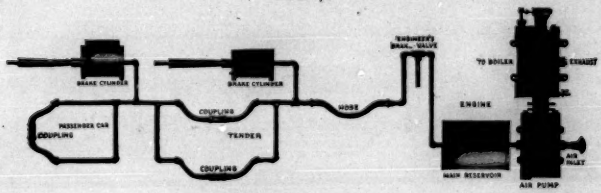
The source of power adopted for this system was the expansive force or pressure of compressed air, obtained from a steam actuated air-pump placed upon the side of the engine, and a reservoir in which the compressed air could be stored. A pipe line from the reservoir was carried throughout the length of the train, connections between vehicles being made by means of flexible hose and couplings. Each vehicle was provided with a cast-iron cylinder, the piston rod of which was connected to the brake-rigging in such a way that when the air was admitted to the cylinder the piston was forced out and the brakes thereby applied. A three-way cock or valve located in the engineer's cab by means of which compressed air could be admitted to the train pipe and thus to the cylinders

on each car to apply the brakes; or the air already in the cylinders and train brake pipe could be discharged to the atmosphere, thus releasing the brakes.

An early form of the Straight Air-Brake is shown in Fig. 7. The air-pump is one of the first forms to come into general use, the so-called "trigger" or "jigger" valve motion and octagonal piston rod being features of particular interest.

This type of apparatus has many good qualities and a very large degree of flexibility, that is, the increase or decrease of the pressure or braking power, so-called, was under the control of the operator to a very marked degree, but had shortcomings which made it unsuitable for use on trains of any considerable length on account of the time required to apply and release the brake and the unequal braking effort throughout

FIG. 7.



Straight air-brake.

the train. More important still, the factor of safety was low; as no warning was given in the event of the hose coming uncoupled, and a parted train meant no brakes. Thus it is seen that it lacked the first essential of an efficient brake, which is, that it must be its own "tell-tale." That is, if an accident occurs to the system, it must result in a brake application instead of a loss of the brake.

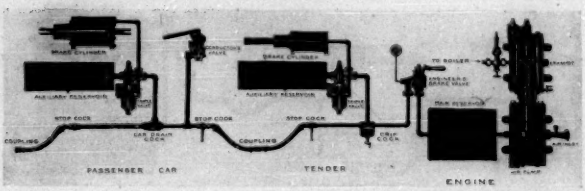
PLAIN AUTOMATIC AIR-BRAKE.

In the natural process and development of railroads, the requirements became more exacting and it was evident that the straight air-brake was not only unsuitable for the reasons just mentioned, but that it lacked essential features. It became more than ever important that the brake must apply automatically,

in case of the train parting. This was so fundamentally necessary that even if the flexibility of the straight air-brake had not already been lost to a large extent by the lengthening of the trains, it would have had to be abandoned because of the infinitely greater safety inherent in a brake of the automatic type. Therefore, the straight air-brake, having served its purpose as an advance agent of something better, gave way to the automatic-brake, which afterwards came to be called the "plain automatic-brake," to distinguish it from a later type that locally reduced the brake pipe pressure, thus producing what is called "quick action."

The first form of this brake, probably the greatest advance ever made in the art, was invented and introduced by Mr. George Westinghouse in 1872 (Fig. 8).

FIG. 8.



The "Westinghouse" plain automatic air-brake, 1872.

The automatic feature resulted from the obtaining of an indirect application of the brakes through the medium of a valve device called a triple valve, and an auxiliary storage reservoir, which were added to the brake cylinder on each car. All of the triple valves were connected together by a continuous pipe, called the brake-pipe, with flexible connections between the cars; this pipe being charged with air whenever the brakes were in operative condition. By this means, the auxiliary reservoir was charged with compressed air for braking purposes on the vehicle to which it was attached; therefore, it was no longer necessary to transmit the air from the locomotive to the vehicle when an application of the brakes was desired. The triple valve is the essential mechanical element in such a system, possessing the three functions of charging the auxiliary reservoir and of apply-

ing and releasing the brakes in accordance with variations in the air pressure carried in the brake pipe; the medium for producing such operations as desired, being, for all general operations, a manually operated brake valve on the locomotive.

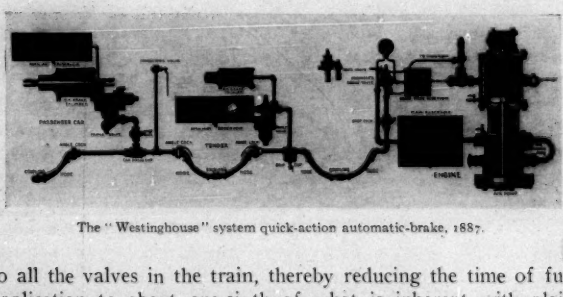
By means of this valve the engineer could apply the brakes either to a part of their capacity, and by steps or graduations, or fully, by a continuous decrease of the brake pipe pressure, but he had no control of the release of the brakes (as with the straight air). The automatic brake releasing locally on each car, while the release of the straight air-brake was controlled on the engine. Therefore, one of the elements of flexibility possessed by the straight air-brake was lost, but, as has been said, this feature had already been very much reduced in value by the lengthening of the train.

Thus, through the instrumentality of the triple valve, the air-brake became automatic, which term applies to that *application* of the brakes which occurs through any material depletion from any cause of brake-pipe pressure, either at the will of the engineer, by hose parting, burst hose, leakage, or at the instance of the train crew, so that this system very materially increased the factor of safety and permitted the use of air-brakes on longer passenger trains, and on the already existing freight trains, in a way that was not possible with the straight air-brake equipment.

QUICK-ACTION AUTOMATIC AIR-BRAKE.—This plain automatic brake was a great improvement in many respects over the straight air-brake, but chiefly from an emergency or safety stand-point, for much of the flexibility (that is, the ability of the operator to increase or decrease the cylinder pressure at will and for any desired number of times in rapid succession) for ordinary service brake operations had to be sacrificed. This brake served the purpose fairly well while trains were short, and speeds, weight and frequency low, but as these factors changed, *its* limitations became more and more apparent, particularly with reference to emergency operation. The application was too slow with long trains, *and for* reasons differing only in degree from those which had affected the straight air-brake. Thus when a quick application was attempted, the shocks were great, nor was the stop as short as required. The reason for this slowness of operation was because the air in the

brake pipe could not be quickly and uniformly reduced throughout its whole length; this, because of increased volume, frictional resistance, and the necessity of its travelling to the one outlet, which was through the brake valve at one end of the train. This limitation was overcome by the invention (in 1887) of the "quick action" triple valve and the equipment with which it was used came to be known therefore as the Quick-Action Automatic-Brake (Fig. 9). The "quick-action" triple valve was identical with the plain triple valve as far as service operations were concerned, but differed from it in emergency in that it automatically vented air from the brake pipe locally on each car. The rapid brake pipe reduction thus resulting is transmitted to the next triple valve and from it serially in the same manner

FIG. 9.



The "Westinghouse" system quick-action automatic-brake, 1887.

to all the valves in the train, thereby reducing the time of full application to about one-sixth of what is inherent with plain triple valves on a 50-car train, and shocks were therefore correspondingly lessened and stops shortened. The reason for this is that the brake pipe reduction with the plain triple valve took place at only one point in the train instead of fifty as with the quick-action valve.

The feature of serial venting of the brake pipe was so important that a second feature of this brake system, which the first mentioned made possible, was, and is to-day, overlooked by many, and perhaps is often not rated at its true value. This feature was the then possible attainment of a different, and higher, braking power for emergency than for service applications. Up to this time the cylinder pressure, or retarding force,

attainable had been the same for both service and emergency applications, but now, since the brake pipe pressure vented could be, and, as a matter of fact, was vented into the brake cylinder with one form of the device, the pressure therein was materially increased whenever quick action took place.

From this it will be seen that to the automatic and graduating features of the brake two others were added, namely, serial quick action and difference or increase in braking power between service and emergency applications. All four of these are now generally recognized (though often not appreciated as they should be) as being fundamentally essential in a brake worthy the name. Moreover, these four features have had and still have great possibilities of extension and development. Attention should be called again to the wonderful adaptability of the original combination of brake cylinder, triple valve, and auxiliary reservoir to the ever-increasing need of more powerful, and what naturally follows, a more flexible brake. *It is truly remarkable that through all subsequent improvements not one of the original functions of the triple valve has been discarded, but that they have been extended and expanded and many new functions added.*

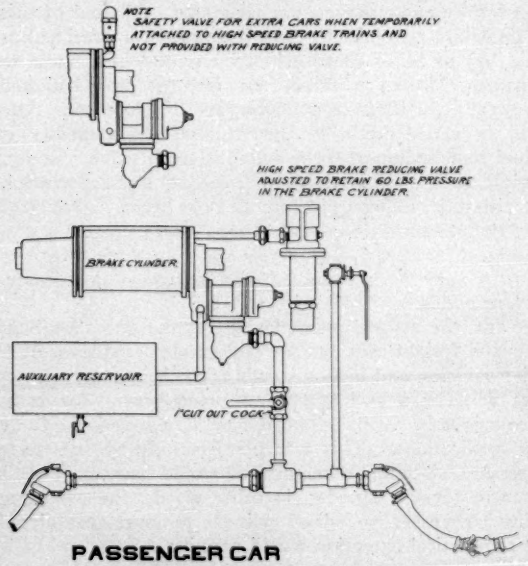
So far, the apparatus employed was the same for both passenger and freight cars, but the still greater frequency of trains, heavier vehicles, and higher speeds made it necessary to provide means whereby a still greater stopping power for passenger service might be available when needed, particularly for emergency applications. This was possible only by increasing the air pressure, since any other method would have made the brake too severe for low speeds; in other words, the percentage of braking power per pound of cylinder pressure was already as great as practical operation would permit.

THE HIGH-SPEED BRAKE.

It was thought, however, that to increase the brake pipe pressure sufficiently to give the desired braking power would result in unpleasant or dangerous shocks, slid and flattened wheels, and other damage from the high brake-cylinder pressure obtainable; therefore, this was not done until the valve known as the "high-speed reducing valve" was perfected in 1894.

The principles utilized by this type of apparatus had been thoroughly demonstrated by the classic Westinghouse-Galton tests in England in 1878. These tests showed that, while the adhesion between the wheel and the rail,—which causes the wheels to persist in their rotation,—is practically uniform at different speeds, the friction between the brake-shoe and the wheel,—which

FIG. 10.


NOTE
SAFETY VALVE FOR EXTRA CARS WHEN TEMPORARILY ATTACHED TO HIGH SPEED BRAKE TRAINS AND NOT PROVIDED WITH REDUCING VALVE.
HIGH SPEED BRAKE REDUCING VALVE ADJUSTED TO RETAIN 60 LBS. PRESSURE IN THE BRAKE CYLINDER.
BRAKE CYLINDER.
AUXILIARY RESERVOIR.
1" CUT OUT COCK
PASSENGER CAR

High-speed passenger brake.

acts as a resistance to the rotation of the wheel, and thereby stops the train,—is considerably less when the wheels are revolving rapidly than when they revolve slowly. It was thus demonstrated that a greater pressure not only could be safely applied to the wheels by the brake-shoes, at high speeds, but also that such considerably greater brake-shoe pressure *must* be applied to the wheels at high speeds, in order to then resist

the motion of the train as effectively as it is resisted with a more moderate brake-shoe pressure at low speeds. This was accomplished by the use of a higher brake pipe air pressure with the standard Quick-Action apparatus, with only the addition of a High-Speed Reducing Valve attached directly to the brake cylinders. This device was designed to limit the brake-cylinder pressure obtainable during a service application of the brakes to what was considered safe and necessary, but when an emergency application of the brakes was made, to permit the brake-cylinder pressure to rise to a considerably higher value than the maximum permitted in a service application, and then to cause a gradual reduction of brake-cylinder pressure, quite slow at first, but becoming more rapid, so as to proportion, as far as possible, with such a device working on a fixed range, the blowdown of brake-cylinder pressure to the reduction in speed as the stopping point is approached. Superior stopping capacity was obtained as already stated, by increasing the brake-pipe air pressure from the generally adopted 70 pounds, as used with the Quick-Action Brake equipment, to 110 pounds, which in emergency applications and with the sizes to brake-cylinder then in use would give about 85 pounds cylinder pressure instead of about 60 pounds, or, in other words, raise the nominal percentage of braking power from 90 to 125 per cent. of the weight of the vehicle.

With this improved equipment when an emergency application was made, full cylinder pressure (85 pounds) was quickly obtained, but was automatically reduced to 60 pounds and held at this point by means of the automatic reducing valve. Thus, if the stop was long enough, the initial nominal percentage of braking power was 125 per cent., while the final was 90 per cent., but the actual retardation of the train kept fairly constant due to the difference in the retarding power of the shoes at high and low speeds already mentioned. Though the co-efficient of brake-shoe friction was known to be less at high speeds than at low speeds, it was predicted by many that much wheel sliding would result from raising the nominal power above 100 per cent. of the light weight of the car, but, on the contrary, wheel sliding was lessened and naturally so when the situation is analyzed.

In service applications, the opening from the reducing valve

was larger than in emergency application so that if such a reduction of brake-pipe pressure was made as would cause the brake-cylinder pressure to rise above 60 pounds, the reducing valve would open and vent the air, which otherwise would cause an undesirably high brake-cylinder pressure, to the atmosphere.

This combination, with the quick-action triple valve, is known as the High-Speed Brake, and is illustrated in Fig. 10.

RECENT DEVELOPMENTS IN TRAIN BRAKE APPARATUS.

The typical brake equipments which have been mentioned, namely: straight-air, plain-automatic, quick-action-automatic and the high-speed brake, mark epochs during which the respective equipments were each able to successfully meet the traffic requirements existing for the greater part of the periods during which they were supreme, but as the demands of service became steadily more severe, each in turn gave way to its successor, the improved equipment in each case being in its turn satisfactory for such a time as the conditions which brought it into being were not greatly changed.

This growth, it will be noted, was along lines of improving the degree of efficiency of the fundamental functions of the original plain triple valve, either by increasing the air pressure carried for braking purposes, or by the aid of additions to the valve structure itself, or by the attachment of additional devices to existing apparatus, or by combination of two or more of the expedients just mentioned.

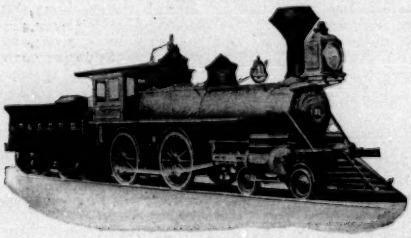
With the high-speed brake, the practical limit to improvement along such lines was believed to have been reached. For some time little or no improvement was thought possible, and this was indeed a fact, so far as further progress along lines previously followed was concerned, for two reasons. (1) About all was then being obtained from the old type of brake that could be gotten from it with the mechanism and arrangement of apparatus then existing. (2) New conditions requiring more specialized apparatus and refinement of the service and emergency features of the brake, as well as of the safety and protective features, began to develop with a rapidity which made it evident that a turning point had been reached.

As a matter of fact, it was rapidly becoming apparent, not

that the air-brake had advanced relatively to the requirements, but that it had not kept pace with the developments of locomotion. In other words, that even the most efficient brake of to-day is, at its best, not able to control and stop a train in the same distance as when the weight and length of the train was less than one-fourth of that to-day. That we have done as well as we have will be appreciated when it is considered that the length of the trains and the volume of air employed have rendered this vastly more difficult, as to service control, and the weight (which involves many factors) to the extent that it would require at least twice the distance in which to stop if the old brake had to be used with present-day conditions.

In addition to the increased weight and speed of trains,

FIG. 11.



American type of locomotive, 1879.

there were, of course, increased number of parallel tracks and frequency of trains. These always bring with them braking problems quite as difficult of solution, and as necessary to be solved, as those which proceeded them, particularly as the tendency is to neutralize or lower the value of many of the factors involved in producing and realizing retarding forces.

It is difficult for one who has not given the subject careful thought to realize the great changes in railroad equipment and operative requirements which have taken place since the introduction of the air-brake, but it is only necessary to review briefly these past and present conditions in order to appreciate the necessity for a similar development and improvement of the apparatus used for controlling trains under these new conditions.

The following comparative tabulations comparing the conditions existing from 15 to 20 years ago and those of to-day with regard to extent of territory covered, capital involved, traffic handled, and so on, will perhaps illustrate the conditions that now have to be faced better than the mere statements which have just been made.

RAILROAD DEVELOPMENT FROM 1889 TO 1909.

	1889	1909	Increase, per cent.
Miles of line	153,385	234,182	52.7
Miles of track	195,958	340,000	73.5
Net capital, etc	$7,366,745,000	$13,508,711,000	63.3
Passengers carried	472,171,000	880,764,000	86.5
Tons freight carried	539,639,000	1,486,000,000	175.3
Locomotives, number	29,036	57,220	97.0
Freight cars, number	829,885	2,113,450	154.6
Employees, number	704,743	1,524,000	116.2
Employees, compensation	$389,785,564	$1,003,270,000	157.4
Electric railways		50,000	

Locomotives.—The weight on drivers has increased since the air-brake was invented, from 25,000 pounds to 400,000 pounds.

The drawbar pull of locomotive has increased, since the air-brake was invented, from 10,000 pounds to 100,000 pounds.

The total weight of locomotives at the present time is as high as 700,000 pounds.

Working steam-pressure has increased, since the air-brake was invented, from 125 pounds to 225 pounds.

Passenger Cars.—Weights have increased from 20,000 pounds to 150,000 pounds.

Freight Cars.—Light weight of car has increased from 12,000 pounds to 50,000 pounds.

Capacity has increased in the last twenty years from 40,000 pounds to 150,000 pounds.

Passenger Trains.—Schedule speeds have increased from 30 miles per hour to 65 miles per hour.

The energy contained in a five-car train of cars having an average light weight of 30,000 pounds per car, running at a speed of 35 miles per hour, is 6,200,000 foot-pounds; of cars having average weight of 127,000 pounds, running at 65 miles

per hour is 90,000,000 foot-pounds, or nearly fifteen times as much.

Freight Trains.—Train length has increased from 15 to 130 cars; total weight has increased from 300 to 4500 tons and in certain places in the country as high as 6000 tons.

To take an actual example illustrating what is involved in the handling of a modern high-speed passenger train, the following figures are taken from the official report of the Emergency Brake Tests carried on about a year ago by the Lake Shore & Michigan Southern Railway near Toledo:

LAKE SHORE EMERGENCY BRAKE TEST.

Types of vehicles used	Weights	
	Pounds	Tons
Locomotive—Pacific type	388,000	194.0
Buffet car	149,000	74.5
Dining car	140,000	70.0
Sleeping car average	125,000	62.5

ENERGY IN TEST TRAINS.

Make up of train	2 Loco.—10 Cars	1 Loco.—6 Cars
Train weight—pounds	2,068,000	1,180,000
Train weight—tons	1,034	590
Energy at 40 M. P. H., foot-pounds	116,816,000	66,595,200
Energy at 40 M. P. H., foot-tons	58,408	33,298
Energy at 60 M. P. H., foot-pounds	262,836,000	149,839,200
Energy at 60 M. P. H., foot-tons	131,418	74,920
Energy at 80 M. P. H., foot-pounds	467,264,000	266,380,800
Energy at 80 M. P. H., foot-tons	233,632	133,190

KINETIC ENERGY* IN TRAIN OF 2 LOCOMOTIVES, 10 CARS OF 75 TONS WEIGHT EACH—TOTAL TRAIN WEIGHT, 2,276,000 LBS. OR 1138 TONS.

Speed	40 M. P. H.	60 M. P. H.	80 M. P. H.
Foot-pounds	127,811,200	287,575,200	511,244,800
Foot-tons	63,906	143,787	255,622

*Kinetic energy in train of 2 locomotives, 10 cars of 75 tons weight each—at speed of 80 M. P. H. is sufficient to raise 1 ton to a height of over 48 miles.

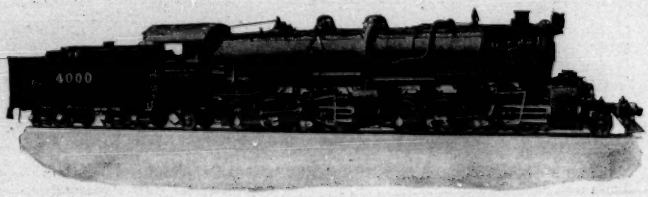
Figs. 11 and 12 present a tangible evidence illustrative of both extremes of the locomotive development indicated in the

tabulations just given. The view of the American type of locomotive (Fig. 11), representing standard practice of 1879 can, no doubt, be recalled by many of you, and is in marked contrast with the enormous Mallet Compound Locomotives (Fig. 12) now being introduced for heavy grade service in various parts of the country.

Similarly the progress in passenger car construction is graphically illustrated by comparing the typical passenger car of 1872 (Fig. 13), with the modern all-steel Pullman cars (Fig. 14), which are being built at the present day.

All the figures which have been given report the maximum conditions of past and present-day practice. As the application of the air-brake has made this enormous increase in weight of vehicles, speeds and length of trains possible, it is fair to assume

FIG. 12.



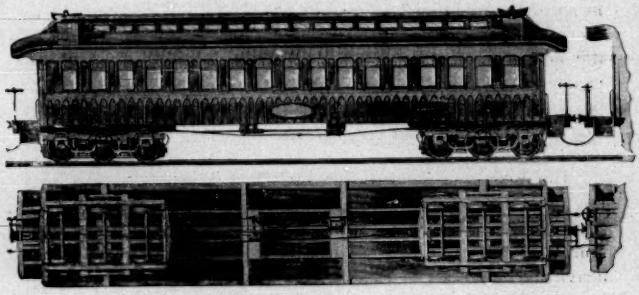
Mallet articulated locomotive—Atchison, Topeka & Santa Fe Ry., 1909.

that the stopping power of the brake should logically be increased in the same proportion so that the stop should be no longer now than formerly.

A concrete example will show forcibly just what this increase in weight and speed means to the operating department if it is to accomplish such an admittedly desirable and necessary result. Under the former conditions the factor of safety in train handling was none too large and it is therefore imperative that we should be able to control modern trains under present existing conditions at least as safely and efficiently as formerly. To do this for five 150,000 pound coaches, running at 65 miles per hour, it is necessary to provide means for controlling over 105,000,000 foot-pounds of energy as compared with about 6,000,000 foot-pounds which was all that the brake

of the early 70's was called upon to control with a train of five 30,000 pounds cars running at 35 miles per hour. When the locomotive used with each train is considered, the total

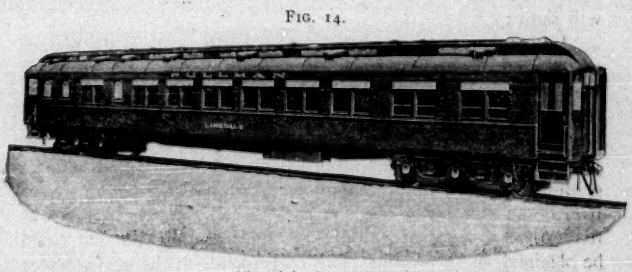
FIG. 13.



P. R. R. passenger car, 1872.

energy in the modern train becomes 162,000,000 foot-pounds, as compare with 9,800,000 foot-pounds, for the train of 1870. It is not surprising, therefore, that the air-brake art demands thoughtful consideration from trained and experienced minds if

FIG. 14.



All-steel sleeping car, 1909.

the railroad traffic of to-day is to be handled with a safety and efficiency even equal to that of the days when the total energy to be reckoned with was one-sixteenth as great. Here again is found another close resemblance between the conditions of ac-

celeration and deceleration, for while it is not especially difficult to increase the speed of a train from 30 miles per hour to 40 miles per hour, it requires the expenditure of a vastly greater amount of energy to increase its speed from 60 miles per hour to 70 miles per hour. In like manner, for any given increase in speed the additional amount of work required from the brake increases in geometrical, not arithmetical, ratio. If, therefore, the improvements for the heavier trains and higher speeds of to-day permit of stopping in about the same distance as could be done with the brake of forty years ago and the trains of that period, we should congratulate ourselves for having held our own.

The mere power necessary to accomplish this is indicated by the fact that the total maximum force exerted by the push rod of the 6-inch brake cylinder of the early equipment was 1700 pounds, while with the 18-inch brake cylinder used on the heaviest coaches, a maximum pressure on the push rod of 26,670 pounds is obtainable.

From the above it will be apparent that many features must now be considered which did not exist when the brake was first invented, particularly on the physical side of the problem. For example, the amount of work required per square inch of brake-shoe surface is vastly greater. This is a condition seldom noticed and yet of great significance, as the following comparison will show:

In the report of one of the earliest brake trials in the history of continuous brakes, made on the Midland Railway, near Newark, England, in 1875, and since known as the Newark trials (see London *Engineering*, June and July, 1875), the best brake performance recorded was by a train of fifteen, 21,000 pound (average), four-wheel carriages, fitted with a primitive form of the Westinghouse Automatic-Brake, one cast-iron brake-shoe being used on each wheel. The best stop was made from a speed of 52 miles per hour, the highest that could be obtained, in 18 seconds. This corresponds to the performance of 15.5 foot-tons (1 ton = 2000 pounds) of work per brake-shoe per second. In the classic Westinghouse-Galton Tests, which followed about three years later, the four-wheel experimental van used weighed 18,200 pounds, and was fitted with two brake-shoes per wheel, and from 52 miles per hour speed a

stop was made by the experimental van alone in 11½ seconds. Here the work done was only about 9 foot-tons per brake-shoe per second.

In 1875 the standard passenger coach used on the Pennsylvania Railroad weighed 39,300 pounds and had four-wheel trucks. To stop such a car from 52 miles per hour in 18 seconds required only 12.33 foot-tons of work per brake-shoe per second, or less than that required of the brake on the Midland train, although the Pennsylvania car weighed 18,300 pounds more. This is, of course, due to the fact that eight brake-shoes were available to do the work as compared with four on the Midland train. Contrast with the above a modern Pullman car weighing 160,000 pounds and having six-wheel trucks. Assuming that from a speed of 52 miles per hour that stop could be made in 18 seconds, the work done would be 33.5 foot-tons per brake-shoe per second, or over twice that of the Midland train, notwithstanding that there are twelve brake-shoes to do the work instead of four. But modern express train speed may be expected to run frequently as high as 75 miles per hour, and to make a stop from this speed in, say, 35 seconds (which would be about the best that could be expected of the modern brake equipment) would require 35.8 foot-tons per brake-shoe per second, or not much more than when a stop of 52 miles per hour is made in 18 seconds. But to have the same absolute safety under modern conditions as existed in 1875 would require the stop to be made in at least the same distance and time, and to stop a 160,000 pound car from a speed of 75 miles per hour in 18 seconds would require 69.6 foot-tons of work per brake-shoe per second or about 4½ times that in the case of the Midland train. (What this would be with four-wheeled trucks will be appreciated.) Even if two brake-shoes per wheel could be used instead of one there would still be over twice as much work to be performed by each brake-shoe per second if the trains of to-day at the speeds now attained in high speed service are to be relatively as safe as the trains of thirty years ago. Furthermore, the use of two brake-shoes per wheel is rapidly becoming a necessity, not only on account of the great amount of work to be performed by each brake-shoe, but also because the brake-shoe pressure required by modern conditions of high speeds and heavy cars are becoming so great that in emergency

applications a heavier pressure is brought to bear on the axle and journals by the brake-shoe acting on one side of the wheel only than is imposed by the weight of the car resting on that wheel.

The tremendous significance of this increase is but faintly appreciated by those who have not had occasion to investigate this aspect of the question. The cast-iron brake-shoe is to-day practically as it was thirty years ago. This brake-shoe must now do four times the amount of work by frictional resistance to the rotation of the wheel, as formerly. It may be suggested, "Why not quadruple the pressure per brake-shoe?" But it also must be remembered that when the brake-shoe pressure is multiplied by four, the actual retarding force is by no means quadrupled, for three vital adverse factors are being overlooked, viz., the effect of increased pressure, speed, and temperature on the coefficient of friction between the wheel and the shoe. Exactly how great an effect these may have depends, of course, on the conditions of the individual test considered, but that it is considerable is proven by the fact that a stop from a speed of 75 miles per hour in 35 to 40 seconds, instead of 18 seconds, is considered good, although we are to-day using about four and a half times as much pressure per brake-shoe as at the Newark trials.

It should be stated that in the above no account is taken of the rotative energy of the wheels. If this is considered, it is evident that the figure for the modern conditions will be still more in excess of those of the past, on account of the wheels being heavier and there being a greater number per vehicle.

Again, the difference in air pressure required to apply and release the brakes is by no means as easily obtained to-day as when trains were short. The air supply required for short trains with small brake cylinders was obtained with compressors of much less capacity than is now necessary to employ: witness, the 6-inch air compressor of the early days of the brake, with its capacity of not over 15 cubic feet per minute, as compared with the cross compound compressors now used, which have approximately 125 cubic feet capacity. The reason for this is apparent, for it required, not so very long ago, about 25 to 30 cubic feet for a full application; now 300 cubic feet is required.

In general, therefore, it may be stated that the brake which would satisfactorily meet the requirements of past conditions, falls short of the maximum efficiency which it should be possible to attain, in proportion to the increase of the requirements of present-day service over those of the past. The force of this is apparent when the same comparison is made between the locomotives and cars of the two periods. This review of the conditions and what is involved, which is by no means exhaustive, will serve to give an idea of the magnitude of the problem. How the various stages of this problem have been solved, as they presented themselves, will be shown best by a consideration of the features and functions of the improved brake apparatus that was developed to meet the conditions just explained.

CHARACTERISTICS OF IMPROVED BRAKE EQUIPMENTS.

While the fundamental service and emergency features of the Quick-Action Brake could not be departed from on account of the necessity for maintaining interchangeability of apparatus, and operative function, it was clear that in designing a brake to meet these new conditions, not only must the fundamental features of the old brake be improved to their highest possible efficiency, but new features must be added, some of which were inherently impossible if the design were carried on along the lines previously laid down.

With this as a point of departure, the development of the newer forms of locomotive, passenger and freight brakes was commenced and it may be fairly said that with the incorporation of the new features which will be explained in what follows, the air-brake entered upon a new era of its history as distinct from that which preceded, covering the progress of the art from the development of the plain automatic brake to the high-speed brake, as that era was distinct from those of the straight air-brake and of the hand-brake which marked the earlier history of the art.

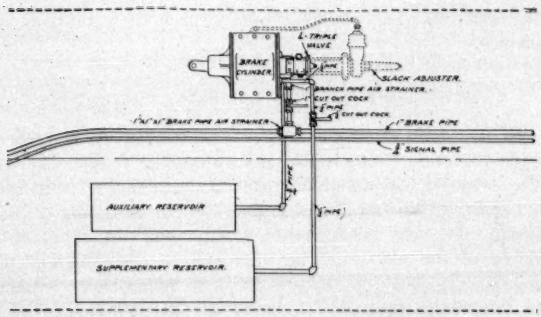
Briefly stated the recognition of the new principles required by the changed conditions referred to, led, in the case of the passenger brake, to the incorporation of the following features

in addition to those characteristic of the previous form of equipment: (See Fig. 15.)

1. Quick rise of brake-cylinder pressure so that the braking power may reach its maximum in the shortest possible time and thus begin to be effective in reducing the speed when at its highest value—and when the increase in distance run before coming to a stop is greatest for every second's delay.

2. Uniform braking power on all cars, irrespective of size of equipment and variation in piston travel, thus contributing largely to the convenience and comfort of passengers, as well

FIG. 15.



Improved passenger brake equipment, type "LN."

as making the brake more reliable and therefore easier to manipulate.

3. Maintenance of both service and emergency-brake cylinder pressures up to the capacity of the ample storage reservoirs of the cars. This is of the greatest advantage in overcoming the ever present and often serious depletion of brake-cylinder pressure by packing-leather leakage.

4. Predetermined and fixed limiting of maximum service braking power, without a safety valve or other blow-off device. This maintains the proper margin between the power of service and emergency applications and tends to reduce wheel sliding without wasting air and with a minimum of apparatus thus resulting in economy both of operation and maintenance.

5. Quick service feature to compensate for increased length of train and bring about more prompt, uniform and certain application of brakes.

6. Quick recharge of the auxiliary reservoirs to offset longer trains and larger cylinders and reservoirs and insure a prompt application of the brakes when desired and prevent the depletion of the auxiliary reservoir pressure.

7. Graduated release feature to add to the flexibility of the brake by making it possible to graduate the brakes off as well as on and so to handle the train more smoothly, with a greater saving of time, and a reduction in the amount of wheel sliding.

8. Much higher brake-cylinder pressure obtained in emergency for the same brake-pipe pressure carried, which pressure is maintained and retained during the complete stop, thus materially shortening the stops and adding greatly to the safety of the trains.

9. Automatic emergency application on depletion of brake-pipe pressure. This is a safety and protective feature of great value, in that it insures sufficient braking power being automatically obtained to bring the train to a stop in case the system is depleted below a predetermined pressure either by careless manipulation or accidentally.

10. Full emergency braking power at any time, thus placing the maximum stopping power the brake has to offer at all times ready for use by the engineer whenever an emergency arises, irrespective of what may have preceded.

11. Separation of service and emergency features so that the necessary flexibility for service applications can be obtained without impairing in the slightest the emergency features of the equipment and conversely, so that undesired quick action is practically impossible.

12. High maximum braking power secured with low total leverage, with correspondingly greater over-all efficiency of the brake.

13. Better mechanical design resulting in more uniform wear of parts and ease of access for removal or repairs.

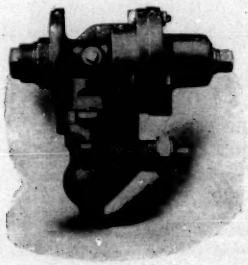
In the case of the freight brake, the change in the conditions which require a change in apparatus were in the direction of greatly increased length of trains, and difference between the

light and loaded weights of the cars. The features of the new freight brake were therefore developed with particular reference to those considerations as follows: (See Fig. 16.)

1. Ability to apply and release the brakes without fear of shocks, under conditions where they are certain with the old brake, gives an added value to all rolling stock.

2. As only a comparatively light reduction is required with the quick service valves to apply all the brakes and with uniform cylinder pressure, there is not sufficient braking power developed in any one part of the train to cause the slack to run in or out severely. On the other hand, with the old brake, a heavy reduction is required to apply the brake at the rear of a long

FIG. 16.



Type "K" freight triple valve.

train, the effect of which is to bunch the slack severely with consequent running out again as the brakes take hold at the rear and the draft springs recoil. As shock is the complement of time and the place where the retarding force is developed, it will be seen that shocks, due to brake applications, will be greatly reduced with the new valve, for while the time required to dissipate the energy of the moving train will be the same, the distribution of the braking power will be different, as it will be divided among all the vehicles in the train instead of first one end and then at the other.

3. Because more applications and release can be made in the same time with the new brake than with the old—much better control and safer operation of the long trains are obtained.

4. On account of the uniform release feature, and because a maximum or full service application of the brake is seldom required with the new brake, the release is more prompt and certain at the rear (which, as has been shown, is the vital place of a long train), and the number of "stuck brakes," flat wheels, and shocks are greatly reduced, particularly as no damage can be caused by the engineer opening the throttle before the brakes at the rear have released.

5. The uniform recharge feature assists in this, inasmuch as the number of "stuck brakes" (resulting from a re-application due to over-charging after a release) is reduced and more equal response of all the brakes secured for subsequent application.

6. The quick service feature makes possible much shorter stops, which is important at all times, but particularly where block signals are in use. This makes unnecessary quick action applications of the brake except in cases of actual danger.

7. The uniform release feature in grade work to a large degree acts as an automatic retaining valve, which is one of the factors in the increased control.

8. The uniformity of application and release tends to reduce the serious effects of the wide difference of braking power with loaded and empty cars in the same train.

9. That vital factor in train control, the personal equation, is made more uniform; as less skill and judgment is required to get good results, while lack of these cannot result in so much harm.

10. As the air required to obtain the same control is only one-third of that required by the old brake, there is much less danger of the supply being inadequate, and with brakes in a reasonably operative condition, there is more likelihood of the engineer stalling or stopping than of "losing his air."

11. Much shifting of lading and breaking-in-two now caused, independent of the brake, by stopping and starting, will be eliminated, as slow downs instead of stops can be made.

12. More tonnage can be handled, and at higher and more uniform speeds, with safety, than has heretofore been possible.

13. Accidents, due to broken wheels, will be fewer, as with the new valve each brake does nearer its share of the work; thus, the excessive heating, due to hand brakes being used, or a few brakes doing the work, no longer takes place.

14. (*a*) The old valves are greatly helped by the new ones when mixed in a train. (*b*) The new features are simply additions to the old valves, the fundamental operative functions and principles remaining the same as in previous forms.

15. With the empty and load brake, greatly increased tonnage can be handled, with equal or even more safety and for mixed empties and loads in the same train the elimination of damaging stresses due to inequality of braking power on empty and loaded cars. The characteristics of this equipment and its peculiar advantages merit a more extended description which will follow a little further on.

In the case of the locomotive brake, the new features characteristic of the improved equipment were naturally in part due to the necessity for bringing the locomotive equipment up to an equal efficiency with the improved passenger and freight brake apparatus as just outlined.

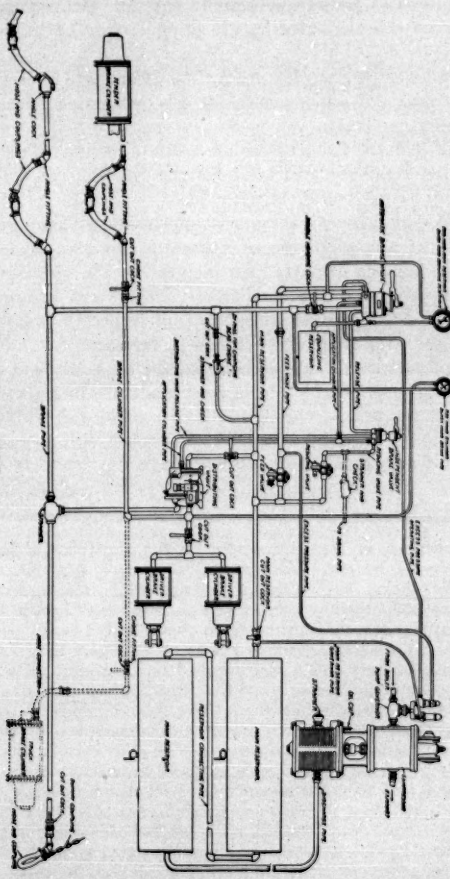
In addition, however, certain desirable operative features had long been recognized, but remained impracticable until the establishment of a new basis for design afforded an opportunity for including in a compact and mechanically satisfactory combination of parts, all that previous experience had shown to be desirable in an efficient locomotive brake (see Fig. 17). Briefly stated these are as follows:

1. Either entirely independent or simultaneous operation of the train and locomotive brakes as may be desired, thus permitting of much greater degree of convenience and flexibility in handling long trains, especially on grades, in switching, etc.

2. Maintenance of brake-cylinder pressure whether partial or full application, up to the capacity of the compressor, thus insuring that the desired amount of braking power on the engine will be obtained and maintained irrespective of the leakage which is so difficult to prevent in the case of locomotive brake cylinders especially.

3. Uniform brake-cylinder pressure in all brake cylinders on the locomotive, irrespective of piston travel, number of cylinders or leakage, thus doing away with the necessity for different size or type of operating mechanism for different sizes of cylinders or types of locomotives as well as insuring against variations in braking power due to differences in piston

travel, which must always be reckoned with on account of the brake-shoe wear or neglect in adjustment.



Piping diagram "ET" equipment.

FIG. 17.

4. Predetermined and desirable increase in emergency brake-cylinder pressure over the maximum obtainable in service, thus

securing for the locomotive brake equipment an advantage long recognized as fundamental for all car-brake equipments.

5. Automatic protection against loss of air required for braking due to brake-valve handle being left in lap position by mistake.

6. Graduated release feature for the locomotive brakes which will then work in harmony with the new graduated release type of passenger car brake.

That the above features are all in the direction of increased convenience, economy and safety in the handling of both passenger and freight traffic, is self-evident, but when it is further considered that these advantageous improvements have been incorporated in a combination of apparatus less complicated and with fewer number of parts than required by the old equipment at its best and that the mechanical design and arrangement of parts has been greatly improved with respect to minimizing the wear due to ordinary service and in increased ease of maintenance and repairs, it will be seen that the character and degree of the improvements which have been made are in accord with, and not antagonistic to, the demands of modern railroad service for apparatus of the highest efficiency coupled with a maximum of economy and a minimum of complexity.

(*To be continued.*)

The Influence of Heat-treatment on the Hardness of Bronze. E. HEYN AND O. BAUER. (*Mitt. Kgl. Material prufungsamt.*, xxviii, 344.)—This shows the value of micrographic investigations in solving practical metallurgical problems. Some new bronze bushes had "smeared" the shafts running in them, and it was desired to find the reason. Chemical analysis showed that they had the same composition as others which had behaved satisfactorily, viz., 93 per cent. of copper and 7 per cent. of tin. Hardness tests proved that the new bushes were softer than the old and microphotographs revealed quite different structures. The hard samples showed two distinct constituents, one rich in copper, the other rich in tin. The soft samples were composed of crystals of copper-tin alloy. The hard samples had been quickly and the soft samples slowly cooled between two critical temperatures, which for an alloy of this composition are 1030° and 850° C. To confirm this view a sample showing the "hard" structure was slowly heated to 900° C., kept at this temperature for half an hour, and allowed to cool during 1½ hours to 765° C. It was then cooled more quickly. The "hard" structure was completely changed to the "soft" structure.

Electric Incandescent Lamps. G. LEIMBACH. (*Z. wiss. Photogr. etc.*, viii, 333.)—For a number of lamps now on the market, the following data have been determined, viz., the watt consumption, the total radiation by the aid of the bolometer, and the luminous radiation in the same way, after the infra-red rays have been absorbed by a solution of ferrous-ammonium sulphate. The results are shown in the following table where *A* represents the specific consumption of watts per mean candlepower, *B* the relative radiating power, *i.e.*, the energy value of the total radiation divided by the energy consumed, *C* the luminous effect, *i.e.*, the energy value of the luminous radiation divided by that of the total radiation, *D* the efficiency, *i.e.*, the energy value of the luminous radiation divided by the energy consumed, *E* the absolute luminous radiation, *i.e.*, the mean spherical luminous radiation divided by the mean spherical candlepower, and *F* the absolute specific luminous radiation divided by the absolute specific luminous radiation of the Hexer candle.

	A	*B*	*C*	*D*	*E*	*F*
		Per ct.	*Per ct.*	*Per ct.*	*Watts per sq. cm.*	
Carbon-filament lamp	3.8	61.9	2.85	1.75	531×10^{-9}	0.62
Nernst lamp	2.0	49.2	4.43	2.17	340×10^{-9}	0.40
Tantalum lamp	2.0	64.8	4.26	2.75	449×10^{-9}	0.52
Osram lamp	1.5	75.6	4.63	3.50	418×10^{-9}	0.49
A. E. G. lamp	1.7	80.5	4.41	3.55	482×10^{-9}	0.56
Bergmann lamp	1.7	68.5	5.03	3.44	473×10^{-9}	0.55
Just Tungsten lamp	1.7	72.2	4.44	3.20	437×10^{-9}	0.51
Sirius colloid lamp	1.5	65.4	5.42	3.55	436×10^{-9}	0.51

Metallic Radium. P. CURIE AND A. DEBIERNE. (*Comptes rendus*, cli, 523.)—A liquid radium amalgam, unstable in air, was prepared by the electrolysis of a solution of 0.106 Gm. of pure radium chloride, using a mercury cathode and a platinum-radium anode. The amalgam was rapidly dried, transferred to an iron boat, and heated in a quartz tube in an atmosphere of pure hydrogen, at a pressure above the vapor pressure of mercury at the temperature of the iron boat. Most of the mercury distilled over at 270° C. and the temperature was then gradually raised to 700° C., when the whole of the mercury appeared to be expelled and the radium began to volatilize; the radium vapor vigorously attacked the quartz tube. The residuum in the boat was a bright, white metal, melting at 700° C., which adhered strongly to the iron. It is rapidly attacked by air, becoming black, probably owing to the formation of a nitride. It blackens paper and decomposes water, mostly passing into solution; the dark colored residue dissolves almost completely on adding a few drops of hydrochloric acid. The radio-active properties of the metal appear to be normal.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, November 16, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1910.

The Stated Meeting of the Institute was called to order at eight o'clock this evening by President Walton Clark.

One hundred and sixty-six members and visitors were present.

The minutes of the previous meeting were read and approved.

A communication from The Board of Managers transmitted the minutes of that body and reported the election of two resident and three non-resident members since the last meeting. The communication was received and ordered to be filed.

The President introduced the Lecturer of the evening, Mr. George Atwell Richardson, President of the Intercollegiate Aeronautical Association of America, Member of the Executive Committee of the Aero Club of America. Mr. Richardson's lecture comprised an historical review of the Art of Aviation from the time of the Greek Legend of Daedalus down through the Middle Ages to modern times, and dealt more particularly with the Science of Aeronautics from the beginning through the invention of the balloon by the brothers Montgolfier on through the successive developments of the Art of Aviation to its present state. The lecture was illustrated by numerous lantern slides and by several kinematographs showing balloons and aeroplanes in motion. Following some brief remarks from the Chair the thanks of the Institute were voted to the lecturer and the meeting adjourned.

L. E. LEVY,
Secretary Pro tem.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 2, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 2, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2496.—Asbesto-Gleam Shade (Longstreth Medal). Adopted.

No. 2481.—Moore Vacuum Tube Light (Scott Medal). Adopted.

For first reading:

No. 2426.—Welin's Life-Saving Appliances on Board Ships.
No. 2455.—Hardinge Conical Pebble Mill (Certificate of Merit). Adopted.
No. 2471.—Anderson Draft Regulator (Advisory). Adopted.
No. 2483.—Hand's Cam Milling Machine (Advisory). Adopted.
No. 2490.—Shuman's Degreasing Machine (Advisory). Adopted.
No. 2503.—Bennett Typewriter.

The Special Committee on the award of the Elliott Cresson Medal appointed September 7, 1910, reported upon the attainments and achievements of the several eminent scientists and technologists named below and recommended that the award of the Elliott Cresson Medal be made to these gentlemen for "distinguished leading and directive work" in their respective fields.

The following motions were accordingly made, seconded, and unanimously carried:

Mr. Rogers moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in electrical discovery and in the advancement of electrical application" to Edward Weston, Esq., D.Sc., LL.D., of Newark, N. J.

Dr. Hoadley moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of the physical sciences" to Joseph John Thomson, Knight, D.Sc., LL.D., Cavendish Professor of Experimental Physics, Cambridge University, England.

Mr. Levy moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of electrical theory" to Ernest Rutherford, Esq., Sc.D., LL.D., Professor of Physics, Owens College, Victoria University, Manchester, England.

Dr. Goldsmith moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the field of agricultural and physiological chemistry" to Harvey W. Wiley, Esq., M.D., Ph.D., LL.D., Chief Chemist to the Department of Agriculture, Washington, D. C.

Mr. Levy moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the production and perfection of instruments for astronomical research" to John A. Brashear, Esq., Sc.D., LL.D., of Pittsburg, Pa.

Mr. Christie moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of the iron and steel industries" to John Fritz, Esq., Bethlehem, Pa.

Mr. Clamer moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of metallurgical science" to Robert A. Hadfield, Knight, Sc.D., LL.D., of Sheffield, England.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Photography and Microscopy.—Stated meeting held in the Hall of the Institute, October 27, 1910. Dr. Henry Leffmann, President, in the Chair; J. W. Ridpath, Secretary. Sixty members and visitors were present.

The meeting was called to order at eight o'clock. The minutes of the previous meeting were approved as recorded.

Dr. Henry Leffmann presented a communication on "Organic and Inorganic Forms Shown with the Projection Microscope." This very interesting lecture was illustrated by nine microscopic slides of vegetable organic forms including sections of seeds, leaves, roots, etc. Eight slides showing animal forms including mosquito and larva, head of tapeworm, proboscis of moth, etc. Also ten slides of rock sections and other inorganic forms shown by polarized light.

After some general discussion upon the habits and possible extermination of the mosquito from the New Jersey coast, the meeting adjourned at 9 o'clock.

J. W. RIDPATH,
Secretary.

Section of Physics and Chemistry.—The Stated Meeting of the Section was held in the Hall of the Institute on November 3, 1910, at eight o'clock, with Mr. Henry F. Colvin in the Chair.

The minutes of the previous meeting were read and approved.

Mr. J. T. Baker, President of the J. T. Baker Chemical Company of Phillipsburg, N. J., delivered a lecture upon "The Theory of Problems in Chemistry."

He discussed the difficulties which arise when the attempt is made to apply on a commercial scale the results obtained by working on a small scale in the laboratory, and drew the conclusion that the chemist is best fitted to overcome these difficulties "who combines a well-balanced amount of both the scientific and the practical mind." The paper was discussed, a vote of thanks was tendered the speaker, and the paper was referred for publication.

On motion the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, November 10, at eight o'clock. Mr. James M. Dodge, Temporary Chairman. Present: 90 members and visitors.

The minutes of the previous meeting were read and approved.

The Chairman then introduced Dr. D. S. Jacobus, Advisory Engineer of the Babcock & Wilcox Company, who presented an interesting communication on the "Production of Power."

The great developments of the art within the last few years were discussed; comparisons were made of failings and advantages of the different means of generation, and a description was given, with numerous lantern slides, of modern power plants and marine practice.

A lengthy discussion followed the paper in which Messrs Hixon, Stratton, Parker, Gartley, Whittaker, Eglin, Crisfield, and others participated.

A vote of thanks was tendered the speaker and the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, November 17, at eight o'clock. In the absence of the Chairman the meeting was called to order by Dr. E. Goldsmith.

After the reading of the minutes of the previous meeting the Chairman introduced Mr. W. V. Turner of the Westinghouse Air-Brake Company, of Pittsburg, Penna., who spoke on the subject of Air-brakes.

A detailed account of the origin and early forms of brakes was given and the various steps in the development of the air-brake were fully described.

Numerous lantern slides covering historic features as well as mechanical details were shown during the reading of the paper.

The thanks of the meeting were extended to the speaker and his paper was referred to the Committee on Publications.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. FRANK H. STIFFEL, 723 Chestnut St., Phila.
MR. ALEXANDER P. ROBINSON, Vice-President, Cambria Steel Co., Phila.

NON-RESIDENT.

MR. DONALD McDONALD, President, Gas Company, Louisville, Ky.
MR. WALTER V. TURNER, Chief Engineer, Westinghouse Air-Brake Co., Pittsburg.
MR. JAMES Z. GEORGE, President and Chemical Engineer, The George Company, Memphis, Tenn.

Changes of Address.

MR. HENRY J. CRUMP, 202 W. Logan Square, Phila.
MR. JOHN RAE, 1908 N. Thirty-second St., Phila.
MR. ARTHUR D. EDGERTON, 614 Pettygrove St., Portland, Oregon.
MR. A. McEACHEN Red Springs, N. C.
MR. EDWIN BURHORN, 938 Hudson St., Hoboken, N. J.
MR. WALTER ATLEE, Room 38, Powelton Ave. and Thirty-second St., Phila.
Mr. PETER H. MURPHY, 722 Frick Building, Pittsburg, Pa.
MR. E. F. MASON, Inspector Motive Power, P. R. R., Altoona, Pa.
MR. JOSHUA L. BAILY, 32 South Fifteenth St., Phila.
MR. S. W. WHITING, 11 Ware St., Cambridge, Mass.
MR. E. A. MULLER, 501 Mitchell Ave., Avondale, Cincinnati, O.
MR. FERDINAND HAYES, JR., Coleman Building, Louisville, Ky.
MR. GEORGE IRA HERRICK, 933 W. Sixth St., Los Angeles, Cal.
MR. WM. E. ALLEN, 1211 Clover St., Phila.

NECROLOGY.

RESIDENT.

Mr. Israel W. Morris, 225 S. Eighth St., Phila.
Mr. J. Henry Hooven, Norristown, Pa.
Mr. M. Riebenack, S. E. Cor. Powelton Ave. and Thirty-fourth St., Phila.

NON-RESIDENT.

Dr. R. G. Nunn, 5 York St., E., Savannah, Ga.
Mr. John Sutcliffe, Bellevue, Pa.

LIBRARY NOTES.

Purchases.

SANG, A.—The corrosion of iron and steel.
DESCH, C. H.—Metallography.
THOMSEN, T. C.—Internal lubrication of steam engines.
KINNICUTT, WINSLOW AND PRATT.—Sewage disposal.
KLEIN AND SOMMERFELD.—Über die theorie des Kreisels. 4 parts.
TURPAIN, A.—Notions fondamentales sur la telegraphie.
TURPAIN, A.—Telephonie. Du telephonie Bell.
D'OCAGNE, M.—Notions elementaires sur la probabilité des erreurs.
BARBILLION AND FERROUX.—Les compteur electriques.
REVILLON L.—La metallographie microscopique.
BAKER, T. T.—The telegraphic transmission of photographs.
ASHE, S. W.—Electricity experimentally and practically applied.
SHELDON AND HAUSMANN.—Dynamo electric machinery.
HALLER AND CUNNINGHAM.—The Tesla high-frequency coil.
TOCH, M.—The chemistry and technology of mixed paints.
Taylor Instrument Companies. Weather and weather instruments.
Engineering News. General Index.

Gifts.

Institution of Civil Engineers of Ireland. Transactions, volume 36. Dublin, 1910. (From the Institution.)
New Jersey Geological Survey. Annual report of the State geologist for 1909. Trenton, 1910. (From the Survey.)
Institution of Naval Architects. Transactions, vol. 52. London, 1910. (From the Institution.)
Canada Department of Customs. Annual report, No. 31, March, 1910. Ottawa, 1910. (From the Department.)
Canada Mines Department. Geology of the Haliburton and Bancroft areas, province of Ontario. Ottawa, 1910. (From the Department.)
Philadelphia Water Bureau. Reports 1905 to 1908. Philadelphia, 1906–1909. (From the Bureau.)
Baltimore, Md., Water Board. Annual reports, 1906–1909. Baltimore, 1907–1910. (From the Board.)
Manchester Association of Engineers. Transactions, 1909–1910. Manchester, 1910. (From the Association.)
Jewish Hospital Association. Forty-fifth annual report. Philadelphia, 1910. (From the Association.)
Buffalo Bureau of Water. Annual report for 1906 and 1909. Buffalo, 1906 and 1909. (From the Bureau.)
Canadian Society of Civil Engineers. Transactions vol. 24, pt. 1. Montreal, 1910. (From the Society.)
Massachusetts Institute of Technology. Register of former students, March, 1909. Boston, 1910. (From the Institute.)
New Zealand Institute. Transactions vol. 42. Proceedings, 1909, pts. 3 and 4. (From the Institute.)

Grand Rapids, Mich., Board of Public Works. Annual reports, 1902 to 1910. Grand Rapids. (From the Board.)

Canadian Mining Institute. Journal, 1907. Montreal. (From the Institute.)

Canada Mines Department. Bulletin No. 3. Ottawa, 1910. (From the Department.)

Hocking Valley Railway Company. Eleventh annual report. Columbus, 1910. (From the Company.)

Nova Scotian Mining Society. Journal vol. 15. Halifax, 1910. (From the Society.)

Yale University. Treasurer's report, 1909–1910. New Haven, 1910. (From the University.)

Institution of Mining and Metallurgy. Transactions vol. 19. London, 1910. (From the Institution.)

Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Nickel, Quicksilver and Silver. Compiled by the Metallgesellschaft, the Metallurgische Gesellschaft, A.G., and the Berg- und Metallbank Aktiengesellschaft. 16th annual issue. Frankfort-on-the-Main, 1910. (From the American Metal Co.)

Div-a-let. Division by letters. A pastime or mental diversion mostly intended for those who are fond of such things. By W. H. Vail, A.M., M.D., Newark, N. J., 1909. (From Mr. Charles Gilpin, Jr.)

U. S. Geological Survey. Professional papers No. 68. The ore deposits of New Mexico. By W. Lindgren, L. C. Graton, and C. H. Gordon. Washington, 1910. (From the Survey.)

Lynn, Mass., Public Water Board. Annual report, 1907 and 1908. Lynn, 1908, 1909. (From the Board.)

Ontario Agricultural Department. Annual report of the live stock associations of Ontario. Toronto, 1910. (From the Department.)

Western Australia Mines Department. Report for 1909. Perth, 1910. (From the Department.)

Fall River, Mass., Annual Reports of the Watuppa Water Board. Fall River, 1910. (From the Board.)

Canada Department of Trade and Commerce. Annual report, 1910, part 2. Ottawa, 1910. (From the Department.)

New York State Museum. Bulletin No. 143. Albany, 1910. (From the Museum.)

BOOK NOTICES.

THE TESLA HIGH FREQUENCY COIL, Its Construction and Uses. By George F. Haller and Elmer Tiling Cunningham. Cloth XII + 119 pages, 7½ x 5½ inches, 56 illustrations. D. Van Nostrand Company, New York, 1910. Price, $1.25 net.

Publications for the guidance of amateur mechanics and electricians do not generally undertake to describe apparatus requiring a degree of technical skill beyond the capacity of the average amateur and descriptions of high frequency coils can scarcely be looked for in such works. To assist the increasing number of advanced amateurs the authors present an account of the construction of a 12-inch coil whose details they have worked out by careful experimenting. With the precise descriptions given and the clear illustrations the book should well serve its intended purpose.

DYNAMO ELECTRIC MACHINERY, Its Construction, Design and Operation; DIRECT CURRENT MACHINES. By Samuel Sheldon, A.M., Ph.D., D.Sc., and Erich Hausmann, E.E., M.S. Eighth edition, completely rewritten. Cloth IX + 328 pages, 7½ x 5½ inches, 210 figures. D. Van Nostrand Company, New York. Price, $2.50 net.

The object sought in the preparation of this work has been the production of a text-book for students in engineering. An engineering student has many tasks to perform in the prosecution of his studies and his time is precious. A subject should for that reason be presented with a view to economize his labor in mastering it in the time allotted. That object has been carried out in the present work.

The introductory chapters contain a brief review of fundamental electric and magnetic laws and facts bearing upon the design of electromagnetic machinery. In the chapters which follow each element of dynamo-machines is presented in a direct and lucid manner and with a conciseness that is well adapted to the needs of the modern technical student. With the exception of the introductory chapters the work has been entirely rewritten, bringing it as fully up-to-date as a text-book well can be. A number of industrial applications, such as motor drives and multiple-unit systems of control add materially to its value in stimulating the reader's interest.

PUBLICATIONS RECEIVED.

Annuaire pour l'an 1911, publié par le Bureau des Longitudes. Avec notices scientifiques. Paris, Gauthier-Villars, 1910. Price, in paper, 1 franc 50c.

A Chip of the Old Block or, at the Bottom of the Ladder. By Edwin J. Houston, A.M., Ph.D. 363 pages, illustrations; 12mo. Philadelphia, Griffith & Rowland Press, n.d.

The Land of Drought or, Across the Great American Desert. By Edwin J. Houston, A.M., Ph.D. 355 pages, illustrations; 12mo. Philadelphia, Griffith & Rowland Press, n.d.

Sur la structure des scories et "terres cuites" trouvées dans la série pampéenne et quelques éléments de comparaison par Félix F. Outes, secrétaire et directeur des publications du Musée de la Plata avec la collaboration du docteur H. Bücking. [De la Revista del museo de la Plata, tome xvii, pages 78 á 85.] 8 pages, plate, quarto. Buenos Aires, Coni Freres, 1910.

Canada Department of Mines, Bulletin No. 3. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. By Eugene Haanel, Ph.D. 76 pages, illustrations, plates; 8vo. Ottawa, Government Printing Bureau, 1910.

La Misura delle deformazioni dei tubi e recipienti cilindrici sollecitati da pressione interna. Ing. Federigo Giordano. 80 pages, illustrations, quarto. Milano, Ulrico Hoepli, 1910.

Der Kautschuk und seine prüfung von Prof. Dr. F. W. Hinrichsen und Dip. Ing. K. Memmler. 263 pages, illustrations, 8vo. Leipzig, S. Hirzel, 1910.

The applications of Collodion Emulsion to three-colour photography, process work, isochromatic photography, and spectroscopic work. Second (enlarged) edition. By Henry O. Klein. 125 pages, illustrations, 8vo. London, A. W. Penrose & Co., 1910. Price, 5 shillings.

Manila Bureau of Science. The mineral resources of the Philippine Islands with a statement of the production of commercial mineral products during the year 1909, issued by the division of geology and mines, Bureau of Mines, Warren D. Smith, chief. 81 pages, plates, maps, 8vo. Manila, Bureau of Printing, 1910.

Installations of the "Chloride Accumulator" on the System of the Gulfport and Mississippi Coast Traction Co. Bulletin No. 125. 8 pages, illustrations, quarto. Philadelphia, Electric Storage Battery Co.

Canada, Department of Mines. Report of analyses of ores, non-metallic minerals, fuels, etc., made in the chemical laboratories during the years 1906, 1907, 1908. Arranged by F. G. Wait, M.A., F.C.S., Chief Chemist. 126 pages, plates, 8vo. Ottawa, Government Printing Bureau, 1909.

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